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Fire Managers Field Guide: Hazardous Fuels Management in Subtropical Pine Flatwoods and Tropical Pine Rocklands

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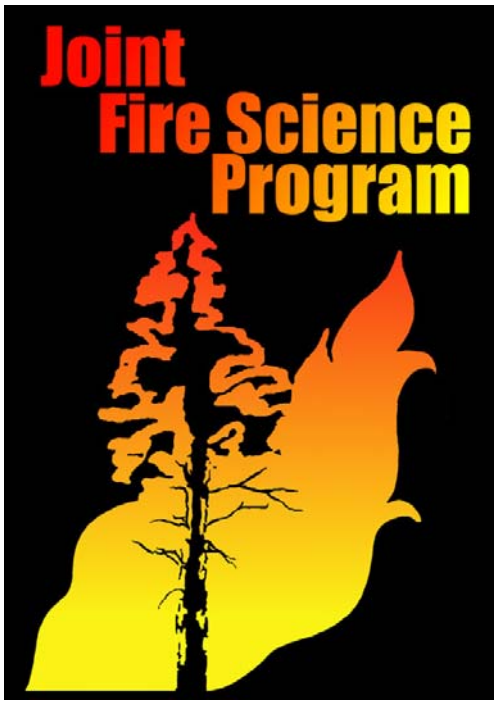

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Preface

This document, *The Fire Managers Field Guide: Hazardous Fuels Management in Sub-tropical Pine Flatwoods and Tropical Pine Rocklands* is intended to provide an overview of techniques and tactics under actual use for addressing hazardous fuels in tropical and subtropical pine forests found in Florida, the Bahamas and elsewhere in the Caribbean. The information presented here was distilled from peer reviewed literature, technical reports, and the experiences of on-the-ground fire managers. Managing fuels is complex and idiosyncratic. This guide is intended to provide only a broad introduction to currently available techniques; some well known and others newer and untested. The goal is to give the fuel manager options and food for thought, not to provide exact prescriptions for dealing with a specific fuel problem. A fire manager must always attend appropriate training and seek out guidance from colleagues and other experts before applying an unfamiliar treatment or experimenting with a new, untested combination of techniques.

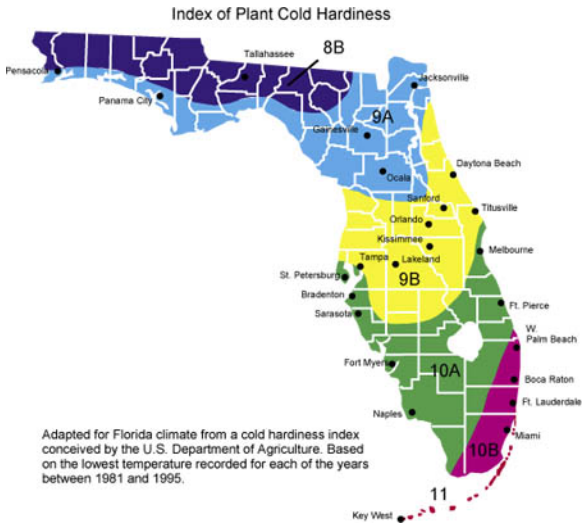
Section I: Introduction

Why was this guide created?

Wildland fires are an integral component of tropical pine rocklands and subtropical pine flatwoods. Fuels in these ecosystems accumulate rapidly and can reach dangerous levels in less than a decade. Land use changes in the regions occupied by these forests have resulted in the exclusion of fire from many areas that formerly burned frequently. Development has resulted in a mix of land uses, some of which are incompatible with fire management. These changes have created challenges for both the management of the forests and the mitigation of wildfire risks. Because of the immediacy of these challenges and the need for action, the Joint Fire Science Board of Directors wanted to create a clearinghouse for hazardous fuels treatments under actual use to guide managers new to the region or unfamiliar with particular issues.

Geographic Scope of the Guide

This guide deals with hazardous fuel issues found in the long needled pine forests known as subtropical pine flatwoods and tropical pine rocklands found Florida and elsewhere in the Caribbean Basin. We define subtropical Florida as the part of the peninsula classified by the Florida Climate Center as hardiness zone 10A, and tropical Florida as hardiness zone 10B or the areas south of Lake Okeechobee including the Miami rock ridge, Big Cypress National Preserve, Everglades National Park and the Florida Keys. We describe these and the Bahamian forests as tropical for climatic reasons, though they lie north of the Tropic of Cancer.



Ecology of Tropical Pine Rocklands and Subtropical Pine Flatwoods

Both tropical pine rocklands and subtropical pine flatwoods are fire dependent ecosystems. The characteristic fire regime for both types of forest consists of low intensity frequent surface fires, recurring every 2-10 years. When burned frequently, ecosystems covered in this guide appear similar structurally, with a tall pine overstory (~12-25 m) a sparse midstory and a species rich understory layer composed of shrubs, palms and herbaceous plants. Overstory pine species vary regionally and with soil type; slash pine (*Pinus elliottii* var. *elliottii*) and some longleaf (*P. palustris*) form the canopy in subtropical Florida flatwoods, South Florida slash pine (*P. elliottii* var *densa*) and Caribbean pine (*P. caribaea* var *bahamensis*) occupying the canopy in rockland ecosystems in tropical Florida and the Bahama Archipelago. Other areas of rocklands exist in Cuba and Hispaniola with different pine species as canopy dominants, but likely behave similarly with regard to fire and fuels.

Tropical Pine Rocklands

Toward the southern tip of Florida, pine rocklands become the dominant pine forest type, differing from flatwoods mainly in substrate and understory plant composition. Pine rocklands are restricted to exposed limestone outcrops in southern Florida, the Bahama Archipelago, and parts of Cuba and the Dominican Republic. Amid the highly eroded limestone are irregularly distributed pockets of slightly basic soils composed of a mix of marls, sands and clays. The type of limestone varies with location, with Pleistocene aged oolitic rock in Florida and the Bahamas and older outcrops in Hispaniola and Cuba. The Floridian and Bahamian limestone is highly eroded and friable making them susceptible to damage by heavy machinery. Forest productivity, and therefore fuel accumulation rates, varies more with precipitation than latitude. Higher rainfall amounts regardless of latitude are associated with higher productivity, more frequent fire return intervals, and more rapid fuel buildup. The unique combination of soils, tropical climate and frequent fires has resulted in the evolution of a diverse plant community. Roughly 30% of the plants found in Florida pine rocklands are endemic.

Pine rocklands were once extensively exploited for both timber and non-timber resources such as coontie (*Zamia pumila*). In Florida, the majority of the original area of pine rockland has been converted to other land uses such as agriculture or residential developments. Most of the remaining Florida pine rocklands are found in parks, refuges or other protected areas. The Bahamas have the most extensive stands of remaining pine rocklands. These stands were once a source of timber, but currently are not exploited. Bahamian rocklands are actively being converted to agriculture, housing and recreational developments.

Several endemic and endangered animals occur either obligately or closely associated with pine rocklands. Examples include the atala hairstreak (*Eumaeus atala florida*), Florida leafwing (*Anaea troglodyta floridalis*), rim rock crowned snake (*Tantilla oolitica*), Key deer (*Odocoileus virginianus clavium*), red cockaded woodpecker (*Picoides borealis*), and Bahama parrot (*Amazona leucocephala bahamensis*). The community is particularly susceptible to invasion by exotic plant species. In Florida, *Schinus terebinthefolius*, *Rhynchelytrum roseum*, *Neyraudia reynaudiana* and *Melaleuca quinquinervia* are particular menaces, since they alter fuels and impact the fire regime. Section 3 provides more information on invasive species and their control.

Subtropical Pine Flatwoods

Subtropical pine flatwoods are savannah-like forests dominated by *Pinus elliottii* (both var. *elliottii* and var. *densa*) and *Pinus palustris* and cover approximately 5.7 million acres in peninsular Florida These forests are much more extensive than pine rocklands and are found over lower pH sandy soils in southern peninsular Florida. The structure of the vegetation is similar to pine rocklands in that there is a pine dominated overstory with a low midstory and species rich understory. Highly flammable shrubs such as gallberry (*Ilex glabra*) and saw palmettos (*Serenoa repens*) dominate the midstory. Productivity is high and fuels accumulate rapidly. Many of the shrubs and palms have highly flammable foliage due to waxes, essential oils and other organic compounds. Those unfamiliar with these forests are often surprised to see how vigorously the green vegetation can burn. Flatwoods dominated landscapes are often a complex mosaic of uplands, wetlands and savannas. Like pine rocklands, these forests are species rich, with a high diversity of herbaceous understory species.

Some areas of subtropical pine flatwoods are still exploited for timber, grazing, and no-timber resources such as saw palmetto berries. Large areas of flatwoods occur in parks refuges

and other protected areas. Pine flatwoods are susceptible to invasion by exotic plants with several species changing fuel beds and increasing hazardous fuel loads. Examples include cogon grass (*Imperata cylindrical*), downy rose myrtle (*Rhodomyrtus tomentosa*), melaleuca (*Melaleuca quinquinervia*), and old world climbing fern (*Lygodium* spp.). More details on exotic species and their control can be found later in this document.

Rare and Protected Species

There are many endemic or rare species of plant and animals associated with Florida pine rocklands and flatwoods, with many protected by state and/or federal laws. Pine rocklands are especially rich in endemic species with many other examples of rare and endangered taxa found in the Bahamas, Turks and Caicos, Cuba and Hispaniola. Appendices C -F list the protected flora and fauna.

Fire Frequency

The rapid accumulation of pine litter coupled with the swift post-fire recovery of fire tolerant palms and shrubs requires the frequent reapplication of fires or any fuel abatement treatment. The photos below show how fuel loads recovered in only three months following fire in subtropical pine flatwoods. In order to keep fuel loads in check, fire return intervals should be less than 5 years in subtropical flatwoods and less than 10 years in tropical pine rocklands. Besides controlling hazardous fuels, short fire return intervals are positively correlated with understory plant species diversity and lower fuel loads produce less smoke.

1 day post-burn, Maykka River State Park

3 months post-burn, same area.

Fire Seasonality

Fire seasonality is a contentious issue among researchers. Human ignition has dominated the fire ecology of the region for at least the last 200 years and likely as long as the 12,000 years humans have lived in the region. Discounting the importance of human ignitions, some researchers have portrayed lighting as the only natural ignition source and link the timing of highest lightning frequency with the natural burn season. The definition of natural is diffuse and difficult to assess. Using natural as a management target is also difficult as there are no concrete definitions as to what the term means and whether the goal has been reached. Furthermore, potentially natural processes might not be compatible with current management goals. For example, historical post fire mortality rates in old trees might have been significant, yet in the few remnant old growth stands that exist today, a manager might decide that any the loss old trees is unacceptable. Also, some researchers contend that lightning frequency doesn't necessarily correlate with fire frequency or area burned. This is because lightning in Florida can occur any time of year and strikes coupled with high winds and dry conditions are more likely to

occur outside the summer months. When these ignitions occur they can burn large areas as demonstrated by the lightning ignition in the Big Turnaround Complex of 2007.

There is no consensus on the impact of fire seasonality on desired management outcomes in part because fire season and fire effects are often decoupled, that is high severity fires can occur at any time of year. The link between plant phenology and fire seasonality is also poorly understood and no broad patterns have emerged among the plant species studied. Some species such as wiregrass (*Aristida stricta*) flower more after spring or summer burns, while others such as Big Pine partridge pea (*Chamaechrista lineata* var *keyensis*) experience higher mortality after spring and summer burns. Until there is a better understanding of the seasonal effects of fire, a prudent manger might spread burning over several different times of year and monitor fire effects for desirable outcomes. Other practical factors such as fire weather, smoke management and fire crew safety should be of primary concern when deciding to ignite a fire. Constraining the burn season because of poorly understood ecological effects necessarily limits burning opportunities. If areas remain unburned more fuel will accumulate adding to already hazardous fuel loads.

Section II: Fire and Fuels Issues

Fuel Productivity in Flatwoods and Pine Rocklands

Fuel accumulation rates in both ecosystems are fairly high, and are capable of sustaining very frequent fire return intervals ca. 1-5 years. Fuel production varies with site productivity and rainfall; drier, lower productivity sites typically have longer fire return intervals. An example of fuel accumulation rates for flatwoods is shown in the tables below.

Table 1. Fuel loading relative to understory height and time since last burn.

Understory Height (feet)	Age of Rough (Years)							
	1	2	3	5	7	10	15	20
	tons/acre							
1.0	0.4	0.4	0.5	0.6	0.9	1.4	2.6*	4.2*
2.0	1.2	1.3	1.3	1.5	1.7	2.2	3.4*	5.1*
3.0	2.6	2.6	2.7	2.8	3.1	3.5	4.7	6.4
4.0	4.5*	4.5	4.6	4.7	5.0	5.5	6.6	8.3
5.0	7.0*	7.0*	7.0	7.2	7.4	7.9	9.1	10.8
6.0	10.0*	10.0*	10.0*	10.2	10.4	10.9	12.1	13.8
*Not likely to occur in nature.								

Pine litter is an important constituent of fuels, providing both a highly flammable fuel and creating continuity that can carry fire across fuel free patches. The relationship between basal area to fuel loading is shown below.

Table 2. Fuel loading relative to stand basal area and time since last burn.

Basal Area (sq. feet)	Age of Rough (Years)							
	1	2	3	5	7	10	15	20
	ton/acre							
30	1.5	2.5	3.4	4.8	5.9	7.0	8.1	8.4
50	1.6	2.8	3.8	5.4	6.6	7.9	9.0	9.4
70	1.8	3.2	4.3	6.1	7.4	8.8	10.1	10.5
90	2.1	3.5	4.8	6.8	8.3	9.9	11.3	11.7
110	2.3	4.0	5.4	7.6	9.3	11.1	12.7	13.2
130	2.6	4.4	6.0	8.5	10.4	12.4	14.2	14.7
150	2.9	5.0	6.7	9.5	11.6	13.9	15.9	16.5

While shrubs and palmetto fuel loadings eventually reach an asymptote, the litter continues to accumulate and a forest floor develops. A deep forest floor poses a particularly hazardous fuel since when ignited, these fuels can smolder for weeks. Duff fuels are discussed in greater detail below.

There is a complex interaction among stand structure, fine fuel distribution, pine regeneration and fires in both of these ecosystems. The overstory pines supply dead needles that create a critical fine fuel; because they are rich in flammable oils, pine needles are often the only fuel capable of carrying fire across vegetation free patches of mineral soil or rock. In fact, in some longleaf pine forests, needles account for 60% of surface fuel mass. Additionally, pine needles can increase fire intensity when combined with other vegetation where fallen needles "drape" over less flammable fuels, and promote combustion. Understanding the link among canopy structure, fire behavior and pine regeneration is critical for forest mangers regardless of management objectives when pursuing treatments. When manipulating stand structure, a manager should consider potential impacts on fire behavior and subsequent ecological effects, not only for pine regeneration, but on other elements of biodiversity that are fire dependent.

Factors Driving the Accumulation of Hazardous Fuels

Fire management in Florida has become hampered by urban encroachment, smoke management issues, and forest fragmentation. For these and other reasons, fire has been excluded from many stands, resulting in the buildup of dangerous fuel loads. These fuel loads have begun to result in recurrent destructive wildfires. Land use changes have resulted in the establishment of a complex landscape with areas incompatible with fire interspersed with forest or at the other extreme forests existing as islands within urban or suburban development. Once continuous tracts of forest are now fragmented by roads, development and agriculture. These land use changes coupled with a legacy of fire suppression have decreased the frequency of fires and increased the area of lands with hazardous fuels. This matrix of land uses is often referred to as the wildland urban interface (WUI). The WUI is probably the most serious issue facing fire managers working in the tropical pine rocklands and subtropical flatwoods. The WUI multiplies the difficulties, costs, and complexity of hazardous fuel management in both obvious and subtle ways. Prescribed fires become more challenging and costly as an escape could be catastrophic necessitating a greater investment in equipment and personnel. Burns generally must be smaller increasing overhead and smoke management can restrict prescription windows. Since management activities occur in close proximity to the public, other hazardous fuels treatments such as mechanical or chemical treatments can face opposition due to aesthetics or other perceptions on their impact. It is clear that managers working in the WUI must have thorough plans for both treatments and contingencies in the event of a wildfire.

Types of WUI

The WUI can be categorized based into three main categories based on geography. Each category creates unique issues for the hazardous fuels manager.

Boundary WUI: Land uses incompatible or at risk from wildland fire occurs along the boundaries of wildlands. The boundary can be clearly defined.

Intermix WUI: Land uses or structures at risk are interspersed within the wildland. The boundaries between wildland and other land uses are indistinct. The proportion of wildland to non-wildland occurs as a gradient. There is often a checkerboard of land ownership and jurisdictions.

Island WUI: Wildlands exist as islands embedded in a matrix on non-wildland.

Some Issues for fire managers working in the WUI.

Firefighting Tactics: Structural and wildland firefighting tactics must be combined when working in the WUI and these tactics have fundamental differences. Structural firefighting tactics center on direct fire attack usually with water or foam while wildland firefighting generally focuses on indirect attack through the creation of fuel breaks. When wildland fires reach the WUI, wildland and structural firefighters must work as a team and it is critical that all parties understand the tactics and techniques unique to each type of firefighting. Since the training and equipment for structural and wildland firefighters have been developed to support the tactical goals inherent to each form of firefighting, understanding how to effectively and safely integrate these resources must be developed prior to any fires.

Jurisdiction: The WUI often exists as a checkerboard of ownership and jurisdictions. Complications can arise due to the number of agencies that must cooperate when treating hazardous fuels or suppressing fires in the WUI, ranging from command and control to payment for services rendered. Also, confusion over jurisdictional boundaries can lead to tactical issues and responsibilities should be clearly established prior to a crisis situation.

Access: Depending on the level of development, some areas may lack the transportation infrastructure required to allow fire equipment access. Roads may be too narrow for fire trucks or heavy equipment to navigate or bridges may not be able to support the weight. Dead-end roads may create dangerous situations or limit egress in the event of an evacuation order.

Water Supply: Proximity to a reliable water source or municipal water system is a boon for both prescribed fire and suppression activities in the WUI and sources should be identified prior to any emergencies.

What is a hazardous fuel?

There is no simple definition of what is a hazardous fuel. Nonetheless, some criteria must be established to determine whether or not a stand is in a hazardous condition. Fuel loading, type, and arrangement as well as the surrounding environment all contribute determine whether a site should be designated as hazardous. When queried, wildland fire experts in Florida generalized hazardous fuel threats into two main categories:

1) **Fuels that create dangerous fire behavior.**
2) **Fuels that foster smoldering fires and smoke management issues.**

These fire managers further identified fuels that created ***threats to public safety*** and ***threats to natural resources***. Fuels associated with threats to public safety generally had a lower threshold for being considered hazardous than those that were a threat to natural resources. For example, the wildland-urban interface creates situations where fuel loads not considered dangerous in a rural context are defined as hazardous. In general managers refer to time since last fire rather than metrics of fuel loading to define a hazardous fuel. There was a consensus among 50+ Florida fire management experts that more than 5 years without fire in flatwoods and

more than 8-10 years in rocklands can create a hazardous condition. Managers focused less on quantifying fuel loading than on knowledge of fire history to determine whether conditions in a stand were hazardous or not.

Fuels that create dangerous fire behavior.

Heavy fuel loads can obviously increase fire intensity and associated threats. Especially problematic is dense saw palmetto as both green and dead fronds burn with vigor. Also, when palmetto density and fire intensity increase, high pine mortality and low pine recruitment occur and can shift the ecosystem from forest to shrubland as the palmettos are extremely fire tolerant.

Of particular concern is the presence of ladder fuels that can lead to crown fires and increase spot fire potential. Ladder fuels are always a concern to fire managers and are found most frequently in long unburned stands with a tall understory and needle drape, stands infested with invasive plants, dense stands of young pines, and stands with dense thatch or silver palms. Particularly hazardous ladder fuels are invasive climbing ferns such as *Lygodium* spp.

Lygodium as a ladder fuel in pine flatwoods. Photo by Amy Ferriter, SFWMD

Fuels that can smolder or create heavy smoke.

A critical effect of any reduction in fire frequency in pine flatwoods or pine rocklands is the development of an organic soil horizon. In frequently burned stands, fire consumes litter and the mineral soil surface remains mostly exposed. In unburned stands, low litter decomposition rates, especially in xeric sites, results in the formation of a deep forest floor. This forest floor or duff layer is a major problem for fire managers. Fires in duff smolder and are difficult to mop up, produce much smoke and can re-ignite other fuels for weeks or months. Many prescribed fires have escaped weeks or even months after smoldering duff has reignited other fuels. Duff fires also can cause very high overstory pine mortality due to the loss of fine roots and damage to the bole.

Duff layer development after 50+ years without fire.

PRESCRIBED FIRE

Fire Use

Fire is an ecological imperative in pine rocklands and flatwoods. Without fire, dangerous fuel loads accumulate and eventually plant succession will result in the replacement of pine stands with other vegetation types. When dealing with a legacy of fire exclusion or other fuel hazards such as exotic plants species, other fuel reduction techniques can have great utility in preparing a stand for the reintroduction of fire. While these alternatives can be effective in abating fuel hazards, there is no ecological equivalent to fire and each non-fire technique will have tradeoffs.

Detailed prescriptions for using fire as a hazardous fuel treatment will not be dealt with here. This is due to extreme complexity and danger associated with using fire as a fuel reduction technique when fuels have become hazardous. The reason why fuels are called hazardous in the first place is due to their potential for causing extreme fire behavior, fire severity or the potential for loss of life and property. Burning a stand with hazardous fuels is the purview of experts who have extensive experience and have extensive training. Appendix A lists agencies that can guide a forest manager to personnel with the experience and skill necessary to use fire in hazardous fuels. Appendix B gives a list of several guides, certifications and literature that can help gain knowledge necessary to be able to safely and effectively use fire in tropical and subtropical pine flatwoods and rocklands. We do not imply that fire is not useful in treating hazardous fuels, in fact fire can often be the best treatment option, but its inherent risk requires detailed consultation with experts and careful planning.

Once fuel hazards are abated, a regular program of prescribe fire or wildland fire use must be established to control fuels and maintain these fire dependent ecosystems regardless of initial abatement tactics. Many times other options such as mechanical or chemical treatments are more suitable for returning a stand to a condition where the ecological benefits associated with frequent fires can be realized. Whether or not fire itself is the best option for initially reducing hazardous fuels is complicated by many factors such as ability to contain an escape, presence of the WUI, potential damage to the natural resource being restored and smoke production.

Planning

All prescribed fires require careful planning but working in areas with hazardous fuels requires extremely careful preparation. Planning must follow the rules pertaining to prescribed burning found in Florida Statutes Chapter 590 and Florida Administrative Code Chapter 5I-2. The Administrative Code also outlines a Certified Prescribed Burn Manager program administered by the Florida Division of Forestry (DOF) that provides liability protection should problems arise from a certified burn. Becoming a Florida Certified Prescribed Burn Manager would be wise for those working in hazardous fuels. Fire managers may gain DOF certification following successful completion of a comprehensive training program. ***Be aware that local rules might be more stringent than state or federal rules and fire managers must be well versed in all applicable fire regulations. The following information must be checked against current statutes and regulations as changes can occur at any time.***

State regulations require that all prescribed fires whether lit by a certified burner in Florida or not must comply with the following rules:

- A permit must be granted by the Florida Department of Forestry. The permit must be in writing if there is a severe drought emergency.
- Adequate fire breaks must be established around the planned burn area, and sufficient personnel and firefighting equipment for controlling the fire must be on the burn site.
- Personnel must remain on-site until the fire is extinguished.
- The burner must have the landowner consent.
- The fire must not escape the permitted burn area.

Certified burns have these additional requirements:

- A detailed written prescription must be prepared and presented to DOF prior to authorization. The plan includes location, size, and description of the area to be burned, amount and type of vegetation, planned ignition patterns, acceptable weather conditions, responsible personnel, safety, and contingency plans for smoke.
- A certified prescribed burn manager must be on site from ignition to completion of the burn and have a copy of the approved written prescription in possession.
- DOF also requests that certified burners notify adjacent residents of the planned burn and follow up with burn results.

Techniques

Ignition Techniques

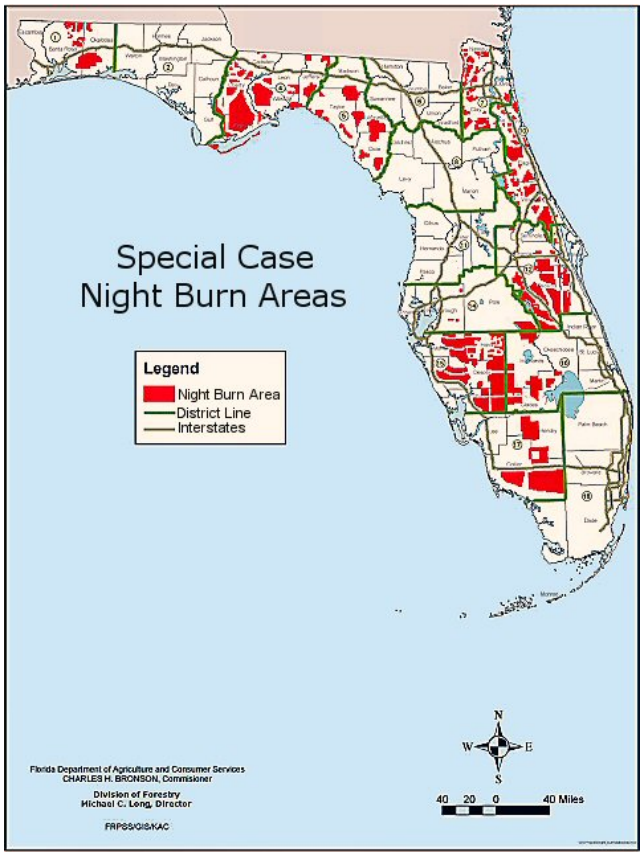
- In general, when working in hazardous fuels, burns should be as small as feasible since smaller burns will be easier to control and produce less smoke.

Often ignition technique will be constrained by smoke management or proximity of the burn unit to other land uses. Many times backing fires must be lit repetitively off the same control lines. This can have undesirable results such as the development of an “edge hedge” where shrubs and palms are not consumed by the low intensity fires and form a zone of heavy fuels adjacent to the firebreaks. Corners where lines meet are especially susceptible to “edge hedge” development. Several managers surveyed successfully used mechanical treatments to abate these fuels.

- Crown Scorch: All the pines found in rocklands and flatwoods are resilient to crown scorch and mortality is generally low even with 100% scorch. While crown scorch is often unavoidable, scorch is a stressor and aesthetically unappealing and should be kept to a minimum.
- Wildlife mortality: Burning isolated fragments should be conducted in order to minimize wildfire mortality. Avoid ignition techniques that ring stands to provide an avenue for escape.
- Wildlife nesting and reproduction: Consider the reproductive phenology of species of concern when timing ignitions.
- Habitat diversity: If possible plan ignitions to create a mosaic of different burn ages and intensities.

Night Burning

Nighttime burning is permitted in portions of the areas covered by this guide under special circumstances and conditions. Burning at night can be an effective means of limiting fire intensity though can create other problems related to smoke dispersion. Contact the Florida DOF for specific requirements for conducting night burns.



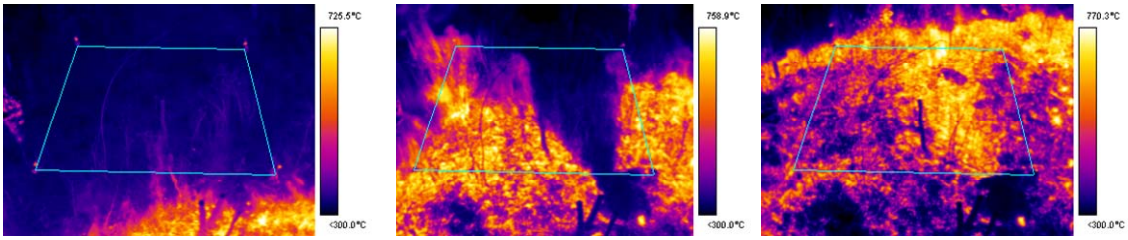
Control Lines

- Common sense dictates that exploiting natural or existing firebreaks whenever possible is a best management practice.
- New fireline construction should minimize impacts to sensitive areas, such as streams or riparian areas, follow topographic contours, and minimize erosion and sedimentation.
- When new firelines are established, managers must exercise care that exotic plant species aren't established. Exotics can quickly negate the effectiveness of a control line as their rapid establishment can create sufficient fuels to carry fire. Ensure that equipment is seed free. Periodic herbicide treatment on the lines will likely be necessary to control invasive species that invade the disturbance.
- In areas with sufficient soil, disking a control line whenever possible instead of plowing minimizes soil disturbance and prevents disruption of surface hydrology.
- Control line establishment in pine rocklands is more difficult because of the limestone substrate. Permanent lines can be created using bulldozers but this method has a high

impact since the structure of the limestone is permanently altered, and the associated rubble can be loci for invasive plant colonization. Blacklining, string trimmers, hand raking/chopping are alternatives in pine rocklands, though these methods have significant tradeoffs such as fire escape risks and high labor outlays.

Fuel Arrangement

Fuel arrangement has a large effect on fire behavior. New research shows that mosaics of different fuel loads can lead to unanticipated fire behavior. In the example shown below, a small fuel free patch in the midst of continuous fuels created a patch of higher intensity fire in its wake. This is because of the head fire splitting into two flanking fires that then recombined with higher intensity as their plumes begin to interact. This pattern appears to occur across scales, from pocket gopher mounds to clearcuts. A major concern for managers is that this phenomenon could initiate crown fires.



Head fire crossing a 5x5 m experimental plot in a longleaf pine stand. These thermal images record higher temperatures as warmer colors. A mound of sand on the lower right border of the plot breaks the headfire into two flanking fires that recombined with higher intensity and quickly re-established the head fire.

Altering fuel arrangement must be carefully considered. Fire managers in the Florida Keys have had success interrupting fuel continuity and reducing fire intensity with mechanical treatments prior to burning. In that case, the machine created multiple continuous strips of compact fuels that snaked through the stand. There is ongoing research on how different fuel arrangements influence fire behavior, but fire managers should be aware that the spatial arrangement of fuels can have unanticipated impacts on fire intensity.

Burning areas with duff

Restoring fire into areas with heavy duff is difficult but not impossible and requires careful planning and narrow prescription windows. The duff must be moist enough not to ignite, yet the surface fuels must be sufficiently dry to burn. ***The objective of restoration fires in heavy duff is not to burn off the duff, but to remove undecomposed litter and prevent further duff accumulation.*** When litter input is consistently removed, decomposition will slowly begin to remove the duff layer. There is some thought that fertilizing with phosphorus might accelerate duff decomposition, but no experiments on efficacy or impacts have been conducted. Restoration of stands with deep duff is a long term proposition and must be approached cautiously if smoldering fires and subsequent high tree mortality are to be avoided.

Though difficult to apply, fire is the best option for removing duff. Other methods such as raking are not practical over large areas and some mangers have observed tree mortality after raking as high as in stands where duff had burned. Since trees invest a significant portion of their fine roots into the duff layer, the destruction of these roots either by fire or raking can cause potentially fatal stress to the trees.

Fire Weather Forecasting

Fire weather is one of the most important and most variable factors facing prescribed fire managers. The Florida Division of Forestry website provides access to a variety of fire weather forecasting resources useful to prescribed fire managers. These include:

Spot Weather Forecasts: These forecasts are meant to augment fire weather forecasts produced by the National Weather Service. These forecasts are available from 8 a.m. to 8 p.m. on any given day and are generated by a numerical weather prediction model developed by Pennsylvania State University and the National Center Atmospheric Research. To generate a spot forecast, uses must know the site latitude/longitude in decimal degrees or the township, section and range numbers. Users then input on-site weather observations of temperature, relative humidity, wind speed and direction, along with the time of the observation. The spot forecasts then provide hourly temperature, relative humidity, wind speed and direction predictions.

Keetch-Byrum Drought Index (KBDI): KBDI is an index of fuel and duff dryness. The scale ranges from 0-800, with higher values indicating increasing wildfire risk. The index increases with consecutive days without rain. The index assumes that 8" of moisture represents a saturate soil. The soil depth required to hold this 8" varies with soil type with a minimum of 30" for sandy soil.

Mesoscale Numerical Forecast Model (MM5): These regional forecasts are generated by numerical models for 7km and 21km. Weather information is supplied as surface and upper air maps, as well as graphics of soundings and cross sections for selected locations. Soundings and 21 km maps are available every 6 hours over a 48 hour period while the 7 km maps and cross sections are available every 2 hours for 24 hours. Soundings show vertical profiles of temperature, moisture and winds while the cross sections show vertical slices of wind, relative humidity and temperature.

Live Fuel Moisture Readings: Live fuel moistures for several sites are available from the DOF and can assist in planning prescribed burns.

Other fire weather products are available from the US Forest Service, National Weather Service, Florida Automated Weather Network (FAWN), and Division of Forestry observations and radar and satellite data.

Smoke management

Concerns over smoke were ubiquitous among the fire managers consulted during the preparation of this guide. Conflicts resulting from reduced air quality from prescribed with both the public and regulatory agencies must be minimized to keep prescribed fire an option for hazardous fuel management. Minimizing prescribed fire impacts on air quality in surrounding populated areas and visibility on roadways must be a priority. Clearly understanding how fire weather effects smoke plume dispersion and settling are critical. To keep smoke under control, managers should attempt to:

- Minimize fuel loads prior to burning through any acceptable means.
- Burn when weather and fuel moisture conditions will minimize smoke production.
- Complete burns as quickly as possible.
- Notify the public and public safety officials of the upcoming burn.
- Keep the public informed that minimizing smoke impacts is a management priority.

Smoke Management Models

The Florida DOF has made a state of the art internet-based smoke management tool available for use by prescribed fire managers available on their website. The Smoke Screening Tool produces a forecast map of smoke plume trajectory and characteristics from a planned burn. Prescribed burners should become familiar with other indices that predict smoke plume behavior such as the Atmospheric Dispersion Index (ADI). Managers must remember that weather conditions amenable for smoke dispersal might cause extreme or unpredictable fire behavior and balancing these two effects requires considerable skill and experience.

Interpretation of Daytime ADI Values

ADI	DESCRIPTION
0-20	Poor dispersion, stagnant if persistent.
21-40	Poor to fair, stagnation may be indicated if accompanied by low wind speeds.
41-60	Generally Good
61-80	Very good dispersion, Control problems likely.
80 +	Excellent dispersion, Control problems expected.

Interpretation of Nighttime ADI Values

ADI	DESCRIPTION
0-2	Poor
3-4	Poor to Fair
5-8	Good
8 +	Very Good

Fire Behavior Prediction Models

Several modeling tools are available for the prescribed fire manager. These models are frequently updated and managers should check with the National Interagency Fire Center for the

latest versions. The generalizations inherent to all models create outputs that must be interpreted with caution. Furthermore, the model output depends on the quality of data inputs: “Garbage in: garbage out.” The current generations of models that are available for field deployment often fail under changing weather conditions or in mosaics of different fuels. Newer models are being developed that will provide better predictions of fire behavior under these conditions and managers should keep an eye out for these newer models. Three widely employed models are BehavePlus, FARSITE and FOFEM. These models require training to be effectively implemented but can augment the experience of a fire manager when planning a burn. These programs can be downloaded from the Fire.org website. The descriptions below were taken from the Fire.org website.

BehavePlus

The BehavePlus fire modeling system is a PC-based program that is a collection of models that describe fire behavior, fire effects, and the fire environment. It is a flexible system that produces tables, graphs, and simple diagrams and can be used for a multitude of fire management applications. BehavePlus is the successor to the BEHAVE fire behavior prediction and fuel modeling system. It is called the BehavePlus fire modeling system to reflect its expanded scope. Development continues with the addition of fire modeling capabilities and features to facilitate application.

FARSITE

FARSITE is a fire behavior and growth simulator for use on Windows computers. It is used by Fire Behavior Analysts from the USDA FS, USDI NPS, USDI BLM, and USDI BIA, and is taught in the S493 course. FARSITE is designed for use by trained, professional wildland fire planners and managers familiar with fuels, weather, topography, wildfire situations, and the associated concepts and terminology.

FOFEM

FOFEM, the First Order Fire Effects Model, is a computer program developed to meet the needs of resource managers, planners, and analysts in predicting and planning for fire effects.

Public Perception of Prescribed Fire

Studies have shown a high acceptance of prescribed fire among the public especially after education on burning techniques and the benefits of controlled and prescribed burning. Public outreach is especially critical in the WUI. Continuous contact with the public is a must if the public will continue to accept prescribed fire as a forest management tool.

Section III: Mechanical Fuel Treatment

Mechanical treatments in this guide are broadly defined as using a machine (generally wheeled or tracked) to alter fuel *arrangement* and/or *load*. The category can be subdivided into roller chopping, mastication (mulching), thinning (with or without removal or piling) and mowing. These treatments are generally more expensive than prescribed fire and often have high impacts on non-target vegetation. Mechanical treatments, though expensive, provide immediate reduction of standing fuel loads. These techniques are most often applied in the wildland urban interface (WUI) or to prepare a long unburned stand for a prescribed fire. The number of manufacturers and types of equipment available for mechanically altering fuels is increasing and ranges from attachments for existing equipment to dedicated fuel treatment devices. Examples offered in this guide imply no endorsement.

Best Management Practice

Choosing a mechanical treatment
Most managers indicated they use mechanical treatments as a preparation for prescribed fires or where fire use might be impossible. This includes creating fire lines, reducing ladder fuels, or knocking down midstory fuels in long unburned sites in an effort to reduce fire intensity.

Selecting a Mechanical Method

There are many options available and these vary in application by region. In Florida, most managers focused on a relatively few types of treatments: thinning, roller chopping, mastication, and mowing.

Thinning
Thinning involves partial harvesting of select trees within a stand. This can be done for economic gains from the harvested trees, to accelerate the growth of the trees left standing, to reduce the crown cover, to remove invasive trees, and in some cases, it is necessary in order to bring equipment into a stand.

Pros
- Reduces live fuels effectively.

Cons
- Can increase downed trees or limbs unless they are harvested or burned.

Length of effectiveness/re-treatment intervals
- Thinning treatments remain effective for one to several years, unless followed up with prescribed burning.

Feller-buncher. Chris Schnepf, University of Idaho

Roller Chopping

This is a site preparation technique in which slash and brush are broken into smaller pieces and flattened. In pine flatwoods, it is often used to thin out palmettos and is reported to be most effective at reducing palmetto cover when palmettos are wet and already stressed. This technique is also effective at treating thickly vegetated edges, and the "edge hedge", an edge effect that is created by prescribed fire ignition techniques. This mechanical method is not recommended for pine rockland habitats.

Roller chopping operation. Jeffrey J. Witcosky, USDA FS

Pros

- Can widen the burn window.
- Can reduce flame lengths.
- Considered a good first treatment in an area infrequently burned such as many newly acquired properties.
- Widely available.
- Feasible way to reduce hazardous fuels in the WUI area.

Cons

- Causes soil disturbance and ground compression. This can be minimized by not double chopping.
- Wheeled prime movers create ruts in soil. This can be minimized by using a tracked vehicle.
- Kills herpetofauna such as gopher tortoises, one way to avoid this is to flag areas where there are burrows in order to reduce damage.
- Roller chopping should not be done in rockland habitat, the machinery will cause long lasting damage to the limestone substrate.

Length of effectiveness/re-treatment intervals

- Usually used once followed by re-introduction of fire.
- If fire can not be re-introduced to treatment area, will need to re-treat every 3-5 years with this method.

Mastication

Mastication is a fuel treatment that changes the structure and size of fuels in the stand. Trees and understory vegetation are chopped, ground, or chipped, and the resulting material is usually left on the soil surface. This treatment method can be done any time of year. This type of method is used to prepare a site before a burn, to create road access, to remove exotic plants, and to remove oak domes.

Debris from mastication treatment. Chris Schnepf, University of Idaho.

Pros

- Can be used in sensitive areas and causes less ground disturbance than chopping.
- Can be used in areas with herpetofauna.
- Creates immediate results.

Cons

- If masticated fuel is allowed to accumulate, it can create a duff layer that could create smoke and smoldering problems during intense or backing fires. One way to reduce smoldering issues is to burn before the chips dry out.
- Ground and chopped material covers up mineral soil and rare plants.
- Many problematic species adapted to disturbance quickly resprout following treatment.
- For larger machines, mastication is typically inefficient at fuel loads of 25 tons per acre or greater.
- In rockland habitat, some managers reported that steel tracked vehicles cause damage to the substrate; this can be minimized by using a vehicle with flexible tracks.

Length of effectiveness/re-treatment intervals

- This method is often a pre-treatment to fire.
- If fire can not be used in treatment area, will need to re-treat every 4-5 years with this method.

Mowing

A mower is a device for cutting plants that grow on the ground, and is applied to such fuels as grass. This type of treatment is used in areas around power lines and in the perimeter zones to reduce the edge hedge. It can also be used to mow lines for strip fires and to create escape routes.

Pros

- This method is a less soil disturbing mechanical option.
- Assists edges to carry fire by creating fine dead fuels and by opening up unit edges to better airflow.
- Can be used in WUI settings.

Cons

- Re-treatment frequency is high.

Length of effectiveness/re-treatment intervals

- Can range from 6 months – 2 years depending on the area being treated.

Understory Biomass Reduction Methods

For further information on a variety of mechanical methods and machinery see these reports**:**

Windell, Keith; Bradshaw, Sunni. 2000. *Understory biomass reduction methods and equipment catalog.* Tech. Rep. 0051-2826-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center.
Also available online at:
http://www.fs.fed.us/forestmanagement/WoodyBiomassUtilization/tools/mtdc-catalog/index.shtml

Beckley, B.; Windell, K. 1999. *Small-area forestry equipment.* Tech. Rep. 9924-2820-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center.
Also available online at:
http://www.fs.fed.us/eng/pubs/pdfpubs/pdf99242820/pdf99242820pt01.pdf

Guidelines of Use

The Prime Mover

The means of moving a treatment device around is called the "prime mover". These can be an integral part of the device, a tractor, or bulldozer that pushes or pulls the device as an attachment. Some dedicated devices still maintain functionality for other uses, for instance, a machine with integral chopping head can still be used to pull a plow or disk to maintain firelines. In general when considering the options available for a prime mover, the manager should strive to minimize soil compaction. Soil compaction is a function of a machine's weight and how that weight is distributed to the ground (ground pressure). The ground pressure of wheeled vehicles is usually greater than tracked vehicles. Tracked vehicles spread the weight over a larger surface, resulting in less compaction. However, in pine rocklands, managers have observed that steel tracked vehicles crush and break up the limestone more than wheeled or flex-tracked machines. As horsepower increases, weight will also increase. Consider your horsepower needs carefully. A heavy machine is also more difficult and costly to transport from site to site. Other considerations are listed below:

Checklist for thinking about a mechanical treatment:

- ✓ **Prime mover**
  - **Wheeled or tracked?**
  - **Steel or flex track?**
  - **Dedicated equipment or attachment?**
  - **Cost?**
  - **Power?**
  - **Maintenance needs?**
  - **Reliability?**
  - **Turning radius?**
  - **Weight?**
  - **Transportation among sites?**
- ✓ **Safety**
  - **Operator protection adequate?**
    - **Protection from falling trees/ limbs**
    - **Protection from thrown objects**

- ✓ **Cutter**
  - **How far do thrown objects travel?**
  - **Treatment swath width?**
  - **Boom mounted or fixed?**
    - **Boom reach and swing?**
  - **Tooth style:**
    - **Fixed, hammer or chain flail?**
  - **Vertical or horizontal shaft?**

Safety/Qualifications of Operator
Operators of heavy machinery should be appropriately trained and licensed. Only properly licensed and trained personnel may operate heavy equipment. Other workers in the area of mechanical operations must be constantly vigilant and never approach heavy equipment unless they are certain the operator knows where they are, what they intend to do and where they intend to go. Personal protective equipment (PPE) should be worn, hard hats and effective eye protection for example. Please refer to your agency's policy regarding specific details on PPE.

Safety zones need to be set up prior to operations, taking into consideration throwback distances. Sites should be cleared of barbed wire and other metals obstacles in order to avoid machinery damage. Extra consideration needs to be taking in the WUI areas.

Communicating with the Operator
Often, mechanical treatments are contracted out and the contracted operator may have different experiences or goals when in comes to treating an area. Therefore it is imperative that the operator clearly understands the land use objectives of the treatment, location of sensitive vegetation or any other ecological concerns, and the property boundaries. Several interviewed managers indicated the critical nature of communication and the disastrous results of miscommunication or lack of supervision.

Potential Issues with Mechanical Treatments

Preventing Breakdowns
Damaged hydraulic lines are a common source of breakdowns. In the event of hydraulic fluid spills, all machines should have a spill containment kit. Simple techniques can reduce machine damage and down time. Avoiding hydraulic hose damage can be as simple as never driving "against the grain" especially with roller choppers. When the brush is knocked down during the first pass, the second pass should be taken in the same direction to prevent the flattened vegetation from snagging lines or more importantly injuring the operator.

Ecological Issues
Mechanical treatments can have a high impact on the site selected for treatment through effects on soils and the rock substrate. Before selecting this type of fuel treatment method, all potential impacts should be considered as well as ways to minimize these impacts.

Compacted Soils

The heavy machinery used in mechanical treatments has the potential to create compacted soils. Some ways to minimize soil compaction include: Applying treatments when soils are dry, matching the size of the equipment to the size and type of vegetation being targeted and treating targeted areas in 1 pass rather than 2 or more. Type of tread used is another factor to consider, although tracked vehicles are heavy, they have lower ground pressure due to having wide treads.

Invasive Species

Soil disturbances create avenues for exotic and weed species invasions. Actions should be taken to reduce disturbance in treated areas. Chopping and mowing exotic grasses has the potential to spread seeds, one way to discourage this is to time treatments before seeds are formed. There is also a potential to spread exotic species seeds through machinery "capturing" seeds in tire or tack treads. In order to ensure that the equipment is not spreading invasive species, vehicles should be washed before moving to another location.

Residual Biomass

Mechanical treatments alter the fuel arrangement but do not remove the fuel. The residual biomass left behind can sometimes cause problems when followed up with a prescribed fire. Chip piles left behind after a treatment can smolder and cause smoke issues and the residual biomass can create duff that will either not burn or burn too well. Timing is important, if fire is to be applied to a site post mechanical treatment, it should be applied soon after and before the residual fuel dries out.

Residual biomass left after a treatment can impact soil and vegetation. Chipped or shredded biomass covers mineral soils, alters soil properties, has unwanted ecological effects, and could create a smoldering fire hazard. One way to reduce this impact is to collect the residual biomass, either during or after treating the site. Depending on the amount, this biomass could be used as mulch in other areas such as walking paths and landscaped sections. It could also be used in the production of alternative energy, such as ethanol.

To learn more about residual biomass use in alternative energy production in Florida see this site for a list of companies: http://www.dep.state.fl.us/energy/energyact/grants.htm

Or Contact:

Florida Department of Environmental Protection
Florida Energy Office
2600 Blair Stone Road M/S #19
Tallahassee, Florida 32399-2400
Phone: (850) 245-8002
Email: energy@dep.state.fl.us

Damage to Non-Target Vegetation

Many important understory plant species in tropical and subtropical pine forests are perennial and are subject to mortality or damage by vehicles. In addition, pine trees can become damaged from contact with the equipment and/or damage to their root system.

If operating in an area that is not invaded by exotic plant species, keep in mind that treating the site in a mosaic pattern will to leave “islands” for seed source as well as for wildlife use.

Wildlife Impacts
Some managers found certain techniques could result in greater mortality to herpetofauna. For instance, roller chopping destroys burrow openings and can kill reptiles. Mortality can be reduced by marking burrow openings prior to treatment in order to avoid them.

Operator Error
Operator error can disturb area treated. It is important to ensure the operator understands sensitive resources and the objectives of the treatment. Contracting with an experienced operator, providing adequate supervision and having good communication can reduce operator mistakes.

Public Perceptions of Fuel Treatments
A post mechanical treatment site can leave a “mowing down the woods” impression. While the public may not approve of the short term appearance of the site, having informational brochures available or interpretive signs at the site can assist in educating the public in regards to the importance of dealing with hazardous fuels and can increase their understanding of the long term benefits that will be achieved.

Costs
The cost of mechanical treatments can vary depending on the site, equipment used, and whether it is done in house or contacted. In general the per-acre cost can range from $100-$500 per acre-

Regulations
Review all Federal, State, Local, and Agency regulations in regards to mechanical fuel treatments before operations to insure compliance.

For more information on regulations see this website:
http://www.sfrc.ufl.edu/Extension/florida_forestry_information/planning_and_assistance/environmental_regulations.html

Or contact your local Florida Division of Forestry office:
Phone: (850) 488-4274
Website: www.fl-dof.com

Section IV: Herbicide Fuel Treatment

Chemical treatments in this guide are defined as using an herbicide to kill or control vegetation. Herbicide treatments are generally more expensive than prescribed fire and can have high impacts on non-target vegetation. These techniques are most often applied in the wildland urban interface (WUI), in areas heavily invaded by exotics plant species, or to prepare a long unburned stand for a prescribed fire. The number of manufacturers and types of herbicides available is numerous and having an understanding of how an herbicide functions and how to properly employ the chemical is crucial when deciding on the type of chemical treatment you select to meet your management objective.

Pesticide Disclaimer Clause: This publication contains pesticide information that is subject to change at any time. This information is provided only as a guide. It is always the pesticide applicator's responsibility, by law, to read and follow all current label directions for the specific pesticide being used; it is also the pesticide applicator's responsibility to follow your agency's policies on pesticide use. No endorsement is intended for products mentioned, nor is criticism meant for products not mentioned. The authors assume no liability resulting from the use of this information.

Best Management Practice

When choosing an herbicide, it is essential to avoid or minimize negative impacts on non-target organisms, including the ability of the soil to hold up desirable vegetation. The site you plan to treat must be listed on the chemical label. *The following questions are useful when making a site-specific decision about which herbicide to use.*

Is the herbicide:

- Effective against the target species?
- Least-toxic to humans and other non-target organisms such as desirable vegetation, animals, and beneficial insects?
- One that requires an adjuvant? If so, is the adjuvant safe to use in areas with sensitive organisms such as salamanders and other amphibians?
- Least-likely to leach into ground or surface water?
- Compatible with vegetation and revegetation programs?
- Compatible with other management methods?
- Quickly degraded in the soil?
- Cost effective?

Selecting an Herbicide

Knowing how an herbicide functions will help you select the best herbicide for the species you are targeting.

Mode of Action

An herbicide is often chosen for use based on its mode of action; some of the most common modes of action include:

- Auxin mimics (2,4-D, clopyralid, picloram, and triclopyr) mimic the plant growth hormone auxin causing uncontrolled and disorganized growth in susceptible plant species.
- Mitosis inhibitors (fosamine) prevent re-budding in spring and new growth in summer, also know as dormancy enforcers.
- Photosynthesis inhibitors (hexazinone) block specific reactions in photosynthesis leading to cell breakdown.
- Amino acid synthesis inhibitors (glyphosate, imazapyr and imazapic) prevent the synthesis of amino acids required for construction of proteins.

Activity

This refers to how the chemical enters the plant. Herbicides are either foliar active, soil active, or both.

- Foliar-active chemicals usually must have adequate leaf surface area in order to be absorbed by the plant, but in some cases foliar-active chemicals can be applied directly to the stem.
- Soil-active chemicals are pulled into the plant through the roots as they take up water and transpire.

Selectivity

The susceptibility or tolerance of different plants to an herbicide is called herbicide selectivity:

- Non-selective herbicides affect all plant types.
- Selective herbicides only affect one type of plant.

Timing of Application

Herbicide timing cannot be described in terms of calendar dates, but instead is described in timing of events:

- Pre-emergent, which is applied to the soil before the plant germinates, can disrupt germination or kill the germinating seedling.
- Post-emergent, which is applied directly to the already established plant or soil.

Guidelines of Use

Listed below are general guidelines of herbicide use. You should always refer to the federal/state/county/agency guidelines for more complete and current policies and information regarding herbicide use and applicator certification programs.

Applicator Certification

Anyone who applies restricted use pesticides to any outdoor area in Florida, not associated with buildings or public health pest control, must have a pesticide applicator license issued by the Florida Department of Agriculture Consumer Services, Bureau of Compliance Monitoring, Pesticide Certification Section.

For more information on Pesticide Applicator Certification & Licensing please see:
http://www.flaes.org/complimonitoring/databasesearch/applcert&licensing.html

Pesticide Certification Section
3125 Conner Blvd., Bldg. 8 (L-29)
Tallahassee, FL 32399-1650
(850) 488-3314

Personal Protective Equipment (PPE)
The health and safety of the applicator are a principal concern. Applicators MUST wear all protective gear required on the label of the herbicide you are using. Please refer to your agency's policy regarding herbicide use for specific details on PPE.

For more information on choosing suitable PPE see:
Pesticide Applicator Update: Choosing Suitable Personal Protective Equipment.
IFAS document PI-28, Pesticide Information Office, University of Florida,
P. O. Box 110710, Gainesville, FL 32611-0710, (352) 392-4721.
http://edis.ifas.ufl.edu/pdffiles/PI/PI06100.pdf

Storage
The proper storage of herbicides is essential to their safe use. Never store pesticides near food, feed, seed, or animals. Designate an area where only pesticides are to be stored. This area should be secured with a lock and a sign reading: Warning-Pesticides-Keep Out. The storage area should be a well ventilated, cool, dry area. The floor should be concrete or lined with plastic to prevent leaks from reaching the soil.
Containers must be carefully stored and should be labeled to indicate the following: contents (ratio of herbicide, adjuvant, water, etc.), date mixed, and approximate volume remaining when placed in storage. Each type of herbicide should be grouped separately (i.e. group all Glyphosate containers together and group all Imazapyr containers together). It is good practice to store containers off the ground on wooden crates to avoid moisture problems. Keep an up-to-date inventory of all chemicals stored, including the date they were purchased, used, and placed into storage.

The storage area should be organized and clean. Have a soil absorbent (e.g., cat litter) readily available at the storage site to help clean up any spills as well as: a shovel, broom, heavy plastic garbage bags and dustpan. In case of fire, always keep a fire extinguisher in the storage area.

Disposal
- Avoid Excess: Excess chemicals and empty containers should be disposed of or stored properly. Avoiding herbicide surplus is the best way to minimize disposal issues. Carefully estimate the amount of herbicide needed to complete the treatment application and buy only what is needed. Determine the size of the area to be treated; calibrate the application equipment; and fill the spray tank with only the amount needed for the application.

- Disposal of Rinse Water and Excess Spray Mixture: Apply excess spray mixture and rinse water generated from rinsing empty containers and spray tanks to a site consistent with label instructions and management objective. Plan ahead for the application of rinse water and excess spray material to the treated area.

- Disposal of Containers: Triple wash or pressure rinse empty containers (jugs, drums, etc). Puncture the container, after rinsing, to prevent reuse. The empty, rinsed container may be taken to a sanitary landfill if the landfill operator and local regulations allow. Empty, rinsed plastic containers may also be taken to a pesticide container recycling program, if one is locally available.
  For more information contact USAg Recycle: www.usagrecycling.com
  or 1-800-654-3554

Spills
Rules and regulations regarding pesticide spills vary between states and counties, therefore, before obtaining herbicides, call the Florida Department of Agriculture and Consumer Services Pesticide Compliance Program (850-488-3314) for up to date information regarding spills and containment in your region.

Record keeping
The records you keep on herbicide use are not only required by the law, they will also help you evaluate you management techniques.

Records:
- Help you evaluate how well a chemical worked, particularly if you have experimented with different concentrations or have used alternative application techniques.
- Help you figure out how much herbicide you will need in a future year, so that you will not have to store or dispose of extra chemicals.
- May protect you from legal action if you are accused of improper use.
- Provide data to respond to surveys conducted by Federal agencies and universities that can impact future availability of some pesticides through re-registration.
- Can be used to respond to the public's concern regarding pesticide use.
- Can save money by helping determine the best pesticide management program.

For a PDF copy of the Florida Department of Agriculture & Consumer Services suggested record keeping form see: http://www.doacs.state.fl.us/onestop/forms/13340.pdf

Or contact the Division of Agricultural Environmental Services for a copy:
3125 Conner Boulevard, Suite F, Tallahassee, FL 32399-1650
(850) 488-3731

Using a Dye
Incorporating a dye will assist in marking treated plants and areas so that no herbicide is wasted. Some pre-mixed herbicides already contain a dye; others such as the ester based herbicide Garlon 4® require oil-soluble dyes which are sold by agricultural chemical and forestry supply companies. Refer to the manufacturer's label for more instructions.

Adjuvants

Spray adjuvants (additives) are added to herbicides to enhance the performance of the herbicide. Adjuvant is a broad term and includes surfactants, oils, antifoaming agents, stickers, and spreaders. It is not always necessary to add an adjuvant.

For more specific information regarding adjuvants please see:
Spray Additives and Pesticide Formulations, IFAS Factsheet ENH82, February 25, 2003; Florida Cooperative Extension Service, http://edis.ifas.ufl.edu/pdffiles/LH/LH06100.pdf

Application Methods

Foliar Treatment
Foliar treatment can be the most cost effective method of herbicide treatments. These methods apply herbicide directly to the leaves and stems of target plants. All foliar treatments should be made after full leaf expansion in the spring and before fall colors are visible. Allow herbicide treatments to dry for at least three hours to allow for adequate absorption.

An adjuvant may be needed to permit the herbicide to penetrate the plant cuticle, a thick, waxy layer present on leaves and stems of most plants. Refer to the manufacturer's label for more information.

Spot Spraying: Rates of one gallon or less per minute at low pressure are recommended. Sprayer should be equipped with a flat spray tip or adjustable cone nozzle. Apply herbicide to the leaves and stems of target plants using a consistent back and forth motion. Herbicide should thoroughly coat foliage, but not to the point of run-off. Complete foliar coverage is needed to be effective. Applications made while walking backward will reduce the risk of the herbicide wicking onto the applicator's clothing.

Worker using backpack sprayer.
USDA Forest Service.

Wick Application – Use in areas where spot spraying is not feasible due to a high concentration of non-target plants. The wick applicator works by becoming saturated with chemical and is then brushed against the target species. Use of a wick eliminates the possibility of spray drift or droplets falling on non-target plants.

Boom Application - A long horizontal tube with multiple spray heads is mounted or attached to a tractor, ATV, helicopter, or small plane. It is carried above the target area while spraying herbicide, allowing large areas to be treated quickly. Non-target areas may be affected by this method from movement of the herbicide due to vaporization or drift.

Aerial herbicide application.
USDA ARS

Basal Sprays
Used for treatment of woody vines, shrubs, and trees. This method applies a band of herbicide penetrant mixture to the lower 12-20 inches of the target stem. The herbicide can be applied with a backpack sprayer or with a wick. Ester formulations are usually best for basal bark treatments since esters can pass readily through the bark, but avoid applying on hot days to prevent vapor drift. Treatment can be performed any time of year; during the summer, treatment is best carried out in the mornings when it is cooler out. Works best on young stems with smooth bark but will not work on older trees with thick bark.

Cut Surface Treatments
Used for treatment of woody species. Herbicide concentrates or mixtures are applied to a freshly cut stem or stump. All cuts should be level, smooth, and free of debris. Herbicide must be applied as quickly as possible after cutting, as a delayed application may reduce the effectiveness of the herbicide. Treatment is most effective in late winter and summer. This method minimizes non-target damage.

Stem Injection Treatment
Used for treatment of woody species with large, thick trunks. Herbicide concentrates or mixtures are applied downwards into cuts made around the circumference of the stem. Treatment is most effective in late winter and in the summer. Avoid using injection during the spring when sap flow is heavy and can wash out the herbicide from the cuts. Also, delay treatment if rainfall is predicted within 48 hours. Herbicides with soil activity can potentially damage nearby non- target plants if washed out from cuts.

Worker injecting herbicide. USDA Forest Service

Injecting herbicide into cut. Utah State University

Potential Issues with Chemical Treatments

Ecological Issues

Herbicides target biological pathways that are unique only to plants (see Mode of Action above). Most modern herbicides such as glyphosate, imazapyr, and hexazinone, degrade quickly, do not persist in the environment, and do not bioaccumulate. When choosing a particular herbicide, be

mindful of its mode of action, its environmental fate, and other characteristics of the chemical as well as the target site conditions (proximity to water, water table depth, and rare species), target species, and what your management objective is.

Some herbicide formulations can not be used in or near water, due to toxicity to fish and other organisms. For example, Ester formulations are toxic to fish because of irritation to their gill surfaces. Certain pre-mixed formulations of Glyphosate are toxic to aquatic organisms due to the adjuvant it contains. Hexazinone is recognized to be toxic to algae. Reading the herbicide label and following instructions as to the habitat it can be used in will prevent herbicide misuse and unintentional consequences.

The best way to minimize unintended ecological impacts of herbicide use is to select herbicides that are effective against the targeted hazardous fuel, will not move offsite by air or water, are nontoxic to people and wildlife, and will not persist in the environment. However there are some circumstances in which a single application of a more toxic or persistent chemical may be preferable. For example: instead of repeated applications of a safer product, using a more toxic herbicide that will require only a single application. Land managers must strike a balance between the strength or effectiveness of the product and the total negative impact on the environment. The information used to make these decisions comes from the herbicide labeling, experienced land managers, herbicide dealers, and other experts.

Adjuvants, additives to herbicides that enhance their performance, do not undergo the same rigorous testing that herbicides do and are not under the same restrictions. Some adjuvants can be toxic to fish, shellfish, and/or other aquatic invertebrates. It is important to read the manufacture label and decide if the formula you choose (whether it contains an adjuvant or if it requires one) will be the best product for your target site and management goals. The herbicide label or Material Safety Data Sheet will specify the best type of adjuvant to use with that herbicide.

For more information please see the following resources:

Chemical Labels and Material Safety Data Sheets are available for free at Crop Data Management Systems' website: http://www.cdms.net

Understanding Material Safety Data Sheet Language: http://edis.ifas.ufl.edu/PI072

Environmental fate, toxicology, and other information on specific chemicals can be found at: http://extoxnet.orst.edu/

Hazardous Fuel

Employing a chemical method to reduce fuel levels will often create a hazardous fuel situation in the short term. This is due to the treated vegetation becoming dry and extremely flammable in the short term, but once the vegetation decomposes it will no longer be a hazardous fuel. Keep this in mind when creating your hazardous fuels management plan.

Damage to Non-Target Plants

Depending on the application method and type of herbicide used (selective/non-selective) some non-targeted plants can be affected by the treatment. For example Journey® which is a mixture of imazapic and glyphosate has been known to kill non targeted pine trees in treated areas. Another example is imazapyr, a non-selective herbicide, which can also cause residual damage to pine trees. To minimize damage to non-target vegetation use herbicides that are appropriate for the species you are targeting and use application methods that reduce spray drift and chemical movement. In some cases non-targeted plants may be unavoidably included in an herbicide treatment. For instance when treating Cogongrass you have to spray all of the grass as well as a 3 foot buffer to treat the rhizomes, in doing so you will invariably kill other plants that are desirable. When making a decision on the use of herbicides as a best management practice for hazardous fuels, you will need to consider possible damage that may occur to other species and weigh the risks with the ecological benefits.

Public Perceptions of Chemicals
The general public perception of herbicide use is negative. This is attitude toward herbicides is due to perceived environmental fate of herbicides and perceived direct toxicity to wildlife. In order to dispel myths concerning herbicide use, educating concerned public on the benefits of herbicide applications and their safety of use when employed properly may assist in alleviating their concerns.

Costs
Herbicide treatment may be costly due to many factors including: size of area being treated, method of application, cost of chemicals, cost of personnel, and cost of re-treatments.

Regulations
Since state and local regulations regarding herbicide use may be more restrictive than Federal regulations, always check and comply with all state and local regulations. Check annual updates from state regulatory and environmental agencies for changes in label restrictions and application policies or permit requirements, before developing or implementing any plans for applying herbicides.

For information of state regulations, visit the Florida Department of Agriculture's website:
http://www.doacs.state.fl.us/onestop/aes/registration.html

Florida Bureau of Compliance Monitoring:
http://www.safepesticideuse.com/

Additional Information

FL Department of Agriculture & Consumer Services
Bureau of Pesticides
3125 Conner Blvd.
Building #6, Mail Stop L29
Tallahassee, FL 32399-1650
1-850-487-0532
http://www.flaes.org/pesticide/index.html

Table of common herbicides used in treating hazardous fuels.

Herbicide	Brand Names	Target Weed Sps.	Activity	Example Prices (Y2007)	Timing	Notes
Glyphosate	RoundUp®, Rodeo®, Accord®	Annual and perennial weeds	Foliar	$62/gal RoundUp	Most effective from late summer through fall, but before significant leaf coloring and drop	▪ Non-selective, ▪ Little to no soil activity: binds tightly to soils and is not persistent ▪ Product has desirable traits regarding environmental effects, but some formulations that are pre-mixed with an adjuvant are highly toxic to aquatic organisms
Hexazinone	Velpar®, Pronone®	Annual, biennials, perennial weeds	Soil and some contact foliar activity	$70/gal Velpar	Early spring to early summer when rainfall necessary for activation is available	▪ Non-selective ▪ Rainfall is necessary for activation ▪ Potential for ground water contamination ▪ Toxic to algae
Imazapic	Plateau®, Plateau Eco-Pak®, Cadre®	Annual and perennial broadleaf weeds and grasses	Foliar and soil	$266/gal Plateau	Late fall, early spring	▪ Selective herbicide for both the pre and post-emergent control of some annual and perennial grasses and some broadleaf
Imazapyr	Arsenal®	Annual and perennial grasses, broadleaves, vines, brambles, brush, and trees	Foliar and soil	$312/gal Arsenal	Any time during the growing season from full foliar development	▪ Non-selective ▪ Provides long-term total vegetation control ▪ Arsenal can cause residual damage to pines
Triclopyr	Garlon®, Remedy®	Woody and annual broadleaf weeds	Foliar with limited soil activity	$91/gal Garlon 3A; $120/gal Garlon 4	Garlon 4 is more effective on woody flatwoods species from midsummer to fall Injection with Garlon 3A can be effective throughout the year except during periods of heavy sap flow in the spring	▪ Selective ▪ The ester formulation is highly toxic to aquatic organisms
Isoxaben	Gallery®	Broadleaf weeds	Foliar and soil	$200/lb Gallery	Late fall, early spring	▪ Selective Pre-emergent
Oryzalin	Surflan®	Annual grasses and broadleaf weeds	Soil	$126/gal Surflan	Late fall, early spring	▪ Selective ▪ Should be applied as a preemergence spray to the soil surface.
Fluroxypyr	Vista®	Annual and perennial broadleaf and woody brush	Foliar	$95/gal Vista	Spring to early summer	▪ Selective ▪ Post-emergence ▪ Improves control on hard-to-control species when used in combination with Garlon® and Tordon® herbicides

Section V: Integrated Treatments for Invasive Plant Hazardous Fuels

Controlling invasive plants in pine rockland and pine flatwoods is key in reducing wildfire fire risk and preserving the health of native ecosystems. This section covers in detail how to treat six plant species that are considered both an invasive species and a hazardous fuel. Treating these types of fuels often involves employing a variety of methods such as prescribed fire, mechanical, and chemical treatments.

Old World Climbing Fern (*Lygodium microphyllum*)

Old world climbing fern (lygodium) is a non-native, invasive fern that climbs high into the tree canopy. It also produces a thick mat of old fern material on the ground that can be up to 3 ft (0.9 m) thick.

Lygodium reproduces by wind-blown spores that are produced throughout the year. A single leaflet can contain up to 28,600 spores.

Identification

Climbing fern is evergreen with dark brown, wiry rhizomes. Fronds climbing, twining, and grow up to 90 ft (30 m) long. Main rachis is wiry, and stem-like. Leaflets can be fertile or sterile with leafy branches off main rachis once compound and the over outline is oblong-like.

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Lygodium spp. SFWMD

Fire Effects

Lygodium is a management concern for both wildfire and prescribed burns: when fire occurs, the fern becomes a ladder fuel, creating flaming mats that carry fire into the canopy, causing intense crown fires. In addition it can carry fire through wet areas which are normally natural barriers to fire and into other fire sensitive areas through spotting (fires ignited outside the desired area).

What you need to know:

When treating this plant it is easy to unintentionally spread its spores. Physically removing or disturbing this fern can cause spore to spread. Equipment and clothing

exposed to this plant can also spread spores to other sites. It is important to be aware of this and wash equipment and clothing before moving on to another site.

The type of herbicide you use will depend on the type of site. For aquatic sites, only herbicides that are labeled for aquatic use can be applied to or above water. Other herbicides can be applied to sites that are seasonally flooded as long as the site does not contain water at the time of application.

Treatment Options

Ground Treatments:

When conducted properly, ground treatments are the most effective way to treat lygodium; unfortunately depending on the site and degree of the infestation it may not be the most cost effective or logistically practical.

Ground treatments with backpack sprayers and hand held sprayers are more selective and can limit damage to non-targeted plants.

A preferred treatment method for ferns that extend high into the canopy is to cut the fern at or below waist height, leaving the clinging portion in the canopy and treating the rooted potion with an herbicide application. This limits disturbance and spread of spores. Fronds that can be reached by hand held sprayer may be left intact.

Treating *Lygodium* with backpack sprayer. SFWMD

Herbicides:

- Glyphosate: rates of 1-3% product (4 lbs/gal) per gallon of water
  Notes: This is a broad spectrum herbicide that will damage non-target plants that it comes into contact with.

- Metsulfuron methyl: rates of 0.02-0.04 ounces product per gallon of water
  Notes: Use of this herbicide results in less damage to non-targeted plants, but can also result in less control of lygodium.
  Due to this plant's nature to sometimes become resistant to a frequently used herbicide, it may be advantageous to experiment with other herbicides.

Aerial Spraying:

Aerial spraying is non-selective and can cause damage to canopy trees and other vegetation. One way to minimize damage is to conduct aerial spraying during winter months when many non-target plants may be dormant.

Herbicides:

- Glyphosate: rates of 7.5 pt product/acre with a surfactant appropriate for site location (check label for instructions).
  Notes: This is a broad spectrum herbicide that will damage non-target plants that it comes into contact with.

- Metsulfuron methyl: rates of 0.05-2.0 ounces product/acre with a surfactant appropriate for site location (check label for instructions).
  Notes: Use of this herbicide results in less damage to non-targeted plants, but can also result in less control of lygodium.
  Due to this plant's nature to sometimes become resistant to a frequently used herbicide, it may be advantageous to experiment with other herbicides.

Follow Up Treatment

Constant surveillance is needed to detect new infestations and to monitor treated areas. Treated sites will need to be re-treated 1-2 times per year for multiple years. New infestations require immediate response in order to contain it.

Additional Information:

For more information on ongoing experiments with different treatments, please visit the Florida Exotic Pest Plant Council website to view the current Lygodium Management Plan: http://www.fleppc.org/publications.htm

Downy Rosemyrtle (*Rhodomyrtus tomentosa*)

Is a fast-growing evergreen shrub that forms a dense growth of bushes and can grow up to 6 ft (1.8. m) tall. It converts a forested understory into a monocultural thicket.

Downy rosemyrtle produces numerous seeds and a high percentage of seed germination. Seeds are dispersed by birds and mammals that eat its fruit.

Identification

Grow as small shrubs or trees that can grow to 6 ft (1.8 m) tall. Leaves are opposite, simple, entire, and elliptic-ovate with glossy green above, densely hairy below. Flowers are rose pink in color, 1 inch (2.5 cm) across, with 5 petals. Fruit is a dark purple berry with aromatic flesh.

Fire Effects

This plant is fire adapted and will resprout abundantly following a fire. It is an emerging problem and is thought to have the potential to alter fire regimes.

What you need to know:
Downy rosemyrtle has proven tolerant of triclopyr herbicide applied by conventional spraying applications. Below are listed methods that have been proven effective. The herbicide tebuthiuron has demonstrated to be ineffective at controlling downy rosemyrtle.

Flatwoods infested with downy rosemyrtle.
Galileo Group Inc.

Treatment Options

Chemical Control:

Triclopyr (ester formulation) best methods:

- Drizzle application in water or oil surfactant at rates of 1 quart per acre.
- Low volume basal bark application (10%-20%) in oil surfactant applied to at least two opposite sides of the main stem, and a repeat application is required. Low output equipment must be used to avoid overdosing.

Physical Control:

If there are small seedlings or small plants they can be pulled or dug out by hand. Plants and fruits should be disposed of properly so that they will not be further spread or become dispersed.

Follow Up Treatment:

Downy rosemyrtle is an emerging problem. Constant surveillance is needed to detect new infestations and to monitor treated areas. Re-treatment intervals have not yet been established. New infestations require immediate response in order to contain it.

Additional Information:

University of Florida IFAS Extension Office: http://edis.ifas.ufl.edu/index.html

Melaleuca (*Melaleuca quinquenervia*)

Introduced into South Florida in the 1900s; has since become one of the most invasive non-native tree species. This tree grows in dense impenetrable thickets and is highly adapted to fire.

Fire facilitates the spread of melaleuca. The disturbance created by fire causes a massive release of stored seeds. Other disturbance events such as girdling, herbicide application, or stem damage will trigger a seed release event as well.

Trees will readily resprout from any point on the bole not killed by fire; also will resprout from cut stumps. Can generate adventitious buds on roots and broken branches may also root and grow if the soil is suitable.

Identification

Mature plants are large evergreen tree up to 108 ft (33 m) tall. Trees are slender and branched with drooping irregular branches. Bark is thick and spongy with papery layers and can range in color from whitish to pale cinnamon. Leaves are dull green, simple, elliptic and densely covered with small hairs when new, then becomes smooth with age. Flowers are crowed in spikes giving a "bottle-brush" appearance. Fruits are square-like woody capsules 0.1-0.2 inches (3-5 cm) long; each capsule contains up to 300 tiny brown seeds and a single tree can store as many as 50 million seeds.

Melaleuca fruits and flowers. USGS

Fire Effects

The thick, papery bark of melaleuca insulates the living tissue of the tree from fire damage while simultaneously carrying the fire into the canopy. Melaleuca leaves contain volatile oils that can create intense crown fires and produce thick, black smoke. Leaf litter created by melaleuca is slow to decompose and can create heavy fuel loads.

Thick smoke from burning melaleuca. NPS

What you need to know:

There are many management options available when treating melaleuca. Due to the nature of this species and its response to treatments (disturbance), no one single treatment type is effective by itself, therefore an integrated approach using multiple methods may be more effective.

Treatment Options

Treating areas infested with melaleuca requires an integrated management plan. Some factors to consider when creating a management plan include: age and degree of infestation, availability of resources (equipment, people), location of the infested site, and its proximity to water.

When using herbicide applications that require a surfactant, surfactant products that contain methylated seed oil have been shown to be most effective.

Cut Stump

These applications are mainly used to treat mature trees greater than 4 feet (1.2 m) tall. Felling trees will cause an immediate seed release and will limit the dispersal of seeds by wind. If trees are left on site, stacking trees limits the sprouting of seedlings to a single area.

Before applying an herbicide to a cut stump, make sure that the cut is made as close to the ground as possible to prevent resprouting and is as level as possible (herbicide will run off of slanted cuts).

Remove any sawdust on the stump, sawdust will soak up the herbicide and prevent it from reaching the stump.

The herbicide should be applied just inside the bark to the living tissue as soon as possible after the cutting.

Hand held sprayers or dropper bottles can be used to apply herbicide. Herbicide should be mixed with a dye in order to keep track of where applications have been made.

Herbicide solutions that have been proven successful:

- Imazapyr: 10-25% solution of product that contains 2 lbs of imazapyr acid per gallon.
- Glyphosate: 50% solution or 100% of product that contains 3-4 lbs per gallon glyphosate acid.

Follow-up Treatment:

In order to remove new seedlings produced from the disturbance created by the cut stump treatment, site can be followed-up with a prescribed fire. Wait about 6-12 months, after seeds have germinated but before they have reached a size where they can withstand a fire. Seedlings <20 inches (<50cm) tall can be killed by fire.

Manual methods such as hand pulling may also be used to remove seedlings and saplings that are shorter that 6.5 ft (2 m). This method is labor intensive and works only in small areas.

Foliar Applications:

These applications are mainly used for treating saplings that are less than 4 feet tall but cannot be pulled out by hand. Can also be used for a large area broadcast application where non-target vegetation does not exist. Be aware that mature trees are difficult to control with foliar applications.

Treat saplings by using a low volume application with hand held equipment or backpack sprayer and herbicide mixtures that have been proven successful:

<u>Glyphosate/Imazapyr mixtures diluted in water:</u>

- 5% solution of product that contains 3-4 lbs per gallon glyphosate acid and 1% solution of product that contains 2 lbs imazapyr acid per gallon, plus a surfactant (if product does not already contain one).

- 3% solution of glyphosate acid and 3% solution of imazapyr acid, plus a surfactant (if product does not already contain one).

<u>Glyphosate</u>

- 5% solution of glyphosate acid with surfactant (if product does not already contain one). Not as effective as above mixtures, resprouting can occur and more follow up treatment will be needed.

Herbiciding melaleuca with backpack sprayers. NPS

Broadcast Applications:

Glyphosate/Imazapyr mixtures:

- 3 lbs glyphosate acid per acre and 1.5 lbs imazapyr per acre, plus surfactant. Apply at a rate of 10 gallons per acre by helicopter, making at least 2 overlapping passes in opposite directions, giving a total rate of 20 gallons per acre applied. Nozzle sizes 0.020-0.030 will provide best coverage.

Follow-up Treatment:

Some trees treated with herbicide have been observed to resprout following a fire. To ensure maximum success of herbicide treatments, wait at least one year after herbicide application before conducting a follow-up burn.

Girdle Applications:

This type of method can be used for isolated trees or for stands where aerial application is not feasible due to location or non-target plants in the area.

Downward cuts are made around the bark using a machete. Cuts should be made deep enough to expose the living tissue. An herbicide should then be applied using a hand held sprayer; an adequate amount should be applied to the girdle to make sure the tissue is thoroughly wet.
While this method of herbicide application can be effective at killing melaleuca and minimizing damage to non-target vegetation, it has drawbacks in efficiency. The method is labor intensive, slow, and costly.

Hack and squirt treatment of melaleuca. SFWMD

Herbicide mixtures that have been proven successful:

- Diluted in water: 25% glyphosate product that contains 3-4 lbs per gallon glyphosate acid and 25% imazapyr product that contains 2 lbs imazapyr acid per gallon.

- Diluted in water: 10 % imazapyr product that contains 2 lbs imazapyr acid per gallon and 50% glyphosate product diluted in water that contains 3-4 lbs per gallon glyphosate acid.

- A solution of 50-100% glyphosate product that contains 3-4 lbs per gallon glyphosate acid can be used alone, but is not as effective as above mixtures, resprouting can occur and more follow up treatment will be needed.

  Follow-up Treatment:

  In order to remove new seedlings produced from the disturbance created by girdle application, site can be followed-up with a prescribed fire. Wait about 6-12 months, after seeds have germinated but before they have reached a size where they can withstand a fire. Seedlings <20 inches (<50 cm) tall can be killed by fire.

  Manual methods such as hand pulling may also be used to remove seedlings and saplings that are shorter than 6.6 ft (2 m). This method is labor intensive and works only in small areas.

Soil Applications:

Granular or liquid herbicides can be applied to the soil and are taken up by the roots. They can be applied by helicopter over the tree canopy in large areas of infestation, or on the ground using a specialized blower.

Herbicide

- 4 lbs Hexazinone per acre, can be in used as either liquid or granular form.

  Follow-up Treatment:

  Treatment area may need to be followed up in order to remove new seedlings produced from the disturbance created by herbicide application. Wait about 6-12 months, after seeds have germinated but before they have reached a size where they can withstand a fire. Seedlings <20 inches (<50 cm) tall can be killed by fire.

  Manual methods such as hand pulling may also be used to remove seedlings and saplings that are shorter than 6.6 ft (2 m). This method is labor intensive and works only in small areas.

Mechanical Methods:

Removing melaleuca with mechanical methods involves using logging or heavy-duty mowing equipment. This type of method can be used to treat mature trees. Seedlings, saplings, and remaining stumps will require follow up treatment with an herbicide application.

Mechanical methods using heavy equipment may not be appropriate for sensitive areas where melaleuca most often occurs. This is due to the disturbance heavy machinery causes to the soil and non-target vegetation.

Biological Control Methods:

Biological controls involve the use of living natural enemies to control pests. This type of method does not eradicate the pest, but is intended to reduce the population density to below economically or environmentally significant levels.

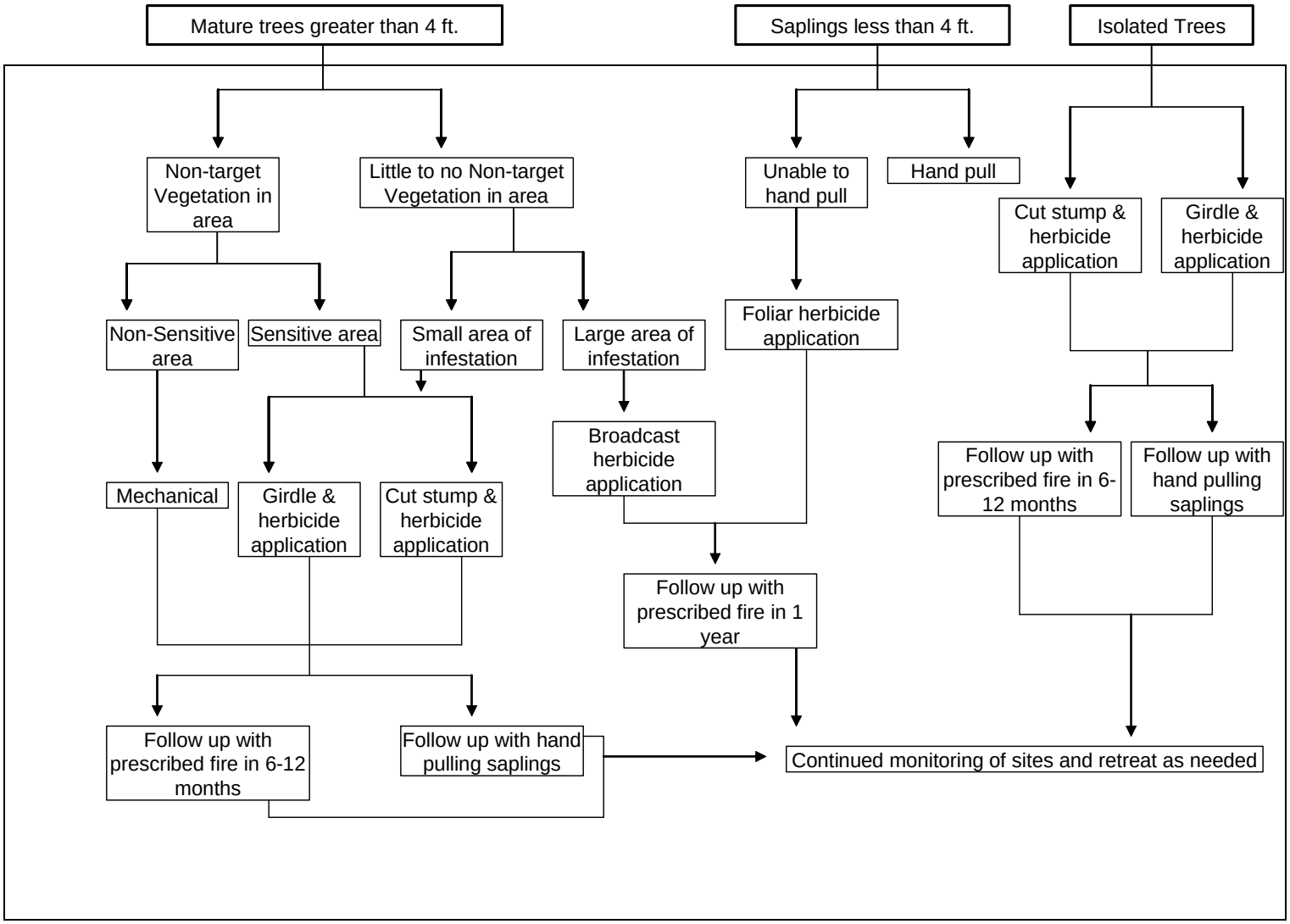
Starting a biological control program requires a consistent commitment of time and money for research, but once the insects have been released and become established, they provide a highly cost-effective tool for suppressing melaleuca. This is because they are free, self-sustaining and self-dispersing.

To find out more about biological controls or to order biological control insects from the University of Florida Institute for Food and Agricultural Sciences (IFAS), please visit this website: http://kgioeli.ifas.ufl.edu/biocontrolorder.htm or by phone: (772) 462-1660

Additional Information

To find out more information on all of the treatment options listed, as well as up to date integrated management plan options, demonstration site updates, and current research, please visit The Areawide Management and Evaluation of Melaleuca (TAME) website: http://tame.ifas.ufl.edu/

To download a copy of their most recent Land Mangers Handbook: http://tame.ifas.ufl.edu/html/documents/LandManagersHandbookNF.pdf



Integrated treatment flow chart for melaleuca control.

Cogongrass (*Imperata cylindrica*)

Cogongrass is one of the most problematic invasive species and is ranked in the top ten of the worst weeds in the world. It is adapted to disturbance, poor soils, high light and low light environments, drought conditions, and fire regimes. In Florida it infests pastures, ditch banks, roadsides, and forests. This grass grows from 2 ft (0.6 m) to over 4 ft (1.2 m) in height and when burned, creates hot flashy fires. It can introduce fire into sensitive areas that are not usually burned and it can change the fire regime of fire dependant ecosystems by altering the structure of the invaded areas.

Identification

Cogongrass grows as a perennial, rhizomatous grass native to Southeast Asia. Grows in loose to compact bunches; each bunch contains several leaves arising from the mid area of the rhizome. Leaves are 1 inch wide, have a prominent off-center white mid-rib, and end in a sharp point. Leaf margins are finely serrated and are embedded with silica crystals (which deter herbivory). Flowers are arranged in a silvery tube-shaped branching structure 3-11 inches (7.6-28 cm) long and 1.5 inches (3.8 cm) wide. Seeds with long fluffy white plumes are produced year round but occur predominately in the spring.

Cogon grass plume. River to River CWMA

Fire Effects

Cogongrass creates hot, flashy fires due to greater fine fuel loads and high biomass density. Temperatures can reach up to 842 ºF (450 ºC) and can reach heights of 5 ft (1.5 m). These hot fires can kill tree seedlings as well as juvenile trees.

What you need to know:

Cogongrass rhizomes are responsible for the survival and short distance spread of the grass. It can quickly recover from cutting and burning due to more than 60% of the plant's total biomass being in the rhizomes; in addition the roots and rhizomes are fire resistant. In established areas, cogongrass produces over 3 tons of rhizomes per acre. The rhizomes are known to produce allopathic chemicals that inhibit the growth of other plant species and once cogongrass is established, the rhizomes grow so dense that

Cogon grass infestation in flatwoods. River to River CWMA

other plant species become excluded and normal ecological succession will not take place.

Treatment Options

There are several different methods that can be used to treat cogongrass, but no one single method is effective alone. In order to effectively control cogongrass an integrated management approach using multiple methods should be considered.

Integrated Management:
There are several steps involved in an integrated management plan. Research has shown the most effectives steps are: mowing or burning, disking, herbicide, revegetation, and follow-up herbicide spot treatments. Your integrated management plan should be tailored to your treatment site and should take into account issues such as site sensitivity and long term management goals. It may not be possible to use all of the methods outlined below, but the most effective control will be achieved by using as many of the steps as possible.

- **Mowing or burning:** This is best done in the spring or summer. It forces rhizomes to produce new shoots and depletes carbohydrate reserves which results in weakened rhizomes.

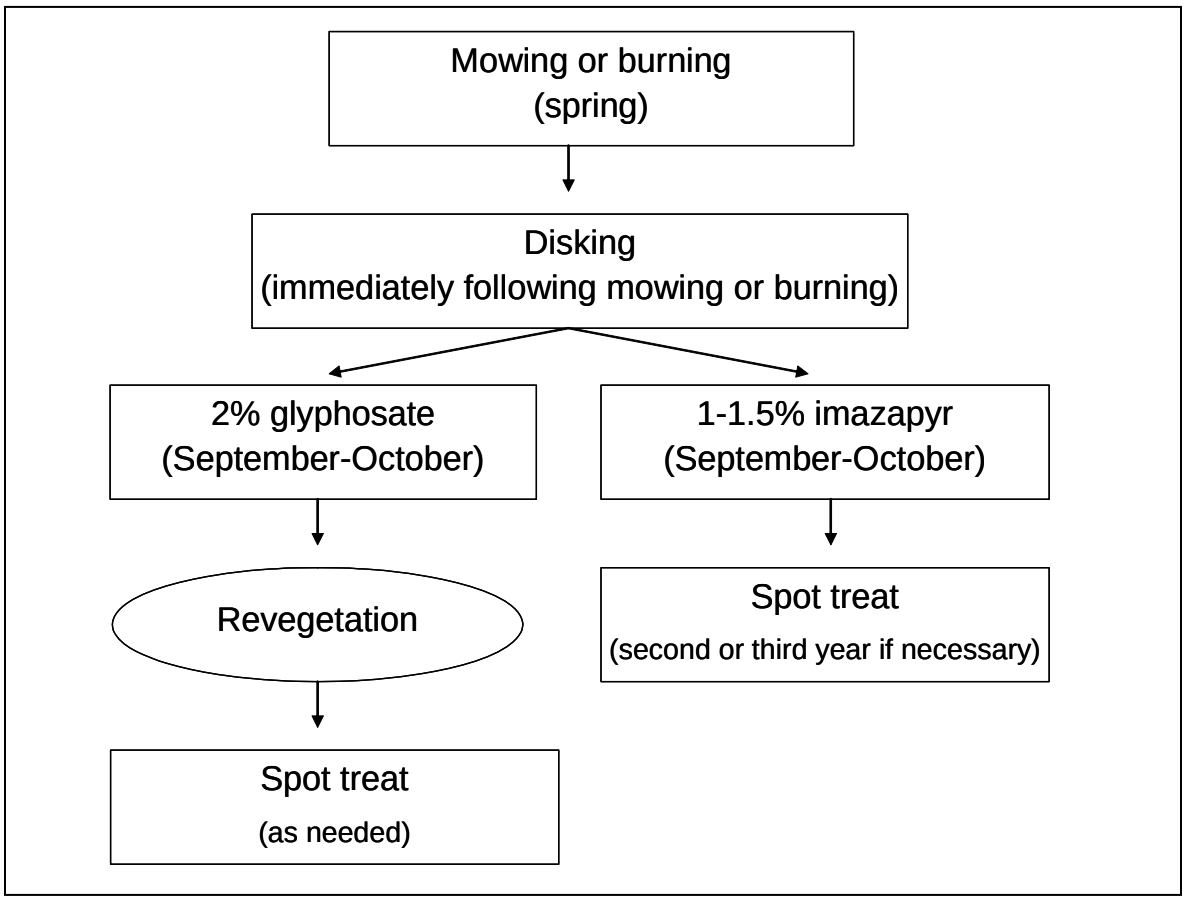
- **Disking or tilling:** After regrowth begins, the treatment area should then be disked or tilled as deeply as possible to break up the weakened rhizomes. This treatment may not be applicable to all areas, especially environmentally sensitive areas.

- **Herbicide:** Treatment is best applied in the fall (from September to October) when there has been sufficient regrowth of above ground shoots. The herbicide application should extend at least 10 ft (3 m) beyond the extent of the infested area. Herbicide trials for treatment of cogongrass have been extensively conducted throughout the world; of all herbicides reviewed imazapyr and glyphosate have been found to be the most effective. The preference in herbicide used depends on your treatment plan. If it includes immediate revegetation, then 2% solution of glyphosate should be used, since it does not have residual soil activity. If no revegetation is planned, a 1-1.5% solution of imazapyr could be used, since it does have residual soil activity. *Keep in mind that due to the high soil activity of imazapyr it has the potential to leach into groundwater, in addition nearby vegetation can be damaged from improper application of imazapyr.*

- **Revegetation:** Introducing desirable vegetation has been found to slow the re-infestation of cogongrass and assists in preventing soil erosion following an herbicide application. Species should be chosen that will compete successfully with cogongrass over the long-term.

- **Follow-up:** Spot treatment using an herbicide may be needed to maintain the treated area. Regular surveillance of treated and untreated areas will assist in determining if cogongrass is present. Identifying the presence of cogongrass and developing an

integrated management plan to prevent further spread will assist in achieving greatest control of this invasive grass.



An integrated approach to cogongrass management in the southeastern United States from Jose, S., Cox, J., Miller, D. L., Shilling, D. G., & Merritt, S. (2002). The story of cogongrass in Southern Forests. *Journal of Forestry*, *100*(1), 41-44.

Additional Information

For up to date publications and treatment methods visit:
www.cogongrass.org

Florida Division of Forestry website with pictures and treatment descriptions:
www.fl-dof.com/forest_management/fh_invasives_cogon.html

Burma reed, cane grass, silk reed (*Neyraudia reynaudiana*)

Burma reed (neyraudia) is an extremely invasive, tall cane grass that is adapted to fire. It invades disturbed sites, dry open habitats, and pine rockland habitat. It prefers dry sites but has been discovered in marshy areas with moist soils. Once established it will invade undisturbed areas. It alters plant communities by shading out understory plants and by creating conditions for extremely hot, destructive wildfires. In pine rockland habitat, the understory is generally 3.3-5 ft

(1-1.5 m) in height. A neyraudia invasion can raise the understory to 13-16.4 ft (4-5 m) in height and increase the fuel load by 3 tons per acre.

Identification

Neyraudia is a tall perennial plume grass that grows to 3-15 ft (1-4.5 m) in height. It grows in clumps, with each clump producing 40 stalks and 12-20 flowering plumes. Flowering plumes are composed of hundreds of tiny flowers and have a silky appearance. Each plume can be up to 3 ft (1 m) in length. Stems are round, solid, and have nodes every 3-5 inches (7.6-12.7 cm). Leaves are 8-10 inches (20-25 cm) long.

Burma reed. NPS

Fire Damage

Neyraudia is adapted to fire, is highly combustible, and is known to alter fire regimes by increasing fine fuel biomass. The increase in biomass results in an increase in fire intensity, higher flame lengths, and increased heat transfer to the canopy, resulting in overstory mortality. The feathery flower plumes carry flames high into the air and can detach causing spot fires (fires ignited outside the desired area). *Neyraudia*'s high flammability promotes frequent fires which enhance the spreading of this invasive grass.

What you need to know:

Early detection and aggressive control is the most effective management approach. Areas infested with neyraudia require long term commitment to ensure successful restoration.

Treatment Options

An effective management option involves an integrated approach using a combination of cutting, mowing, or burning, followed by an herbicide treatment, and revegetation of the site.

Cutting or burning:

- Cutting: If treating individual plants, stalks can be hand cut using a steel blade such as a weed whacker. Cut stems and seed heads should be removed from site taking measures to ensure seeds do not become detached.

- Burning: This method will reduce the plant's stalks to ash and eliminate the cost of vegetation removal.

Herbicide:

Immediately after cutting, the remaining portions of the grass can be sprayed with 2-5% glyphosate mixed with an acidic surfactant in order to prevent new growth. If any further resprouting occurs, the new growth should be treated with a second herbicide application.

After a fire, neyraudia is the first plant to resprout. Once the new growth reaches 12-18 inches (30-46 cm), an herbicide can be applied without concern about non-target vegetation damage. Foliar application of 2-5% glyphosate mixed with an acidic surfactant.

Revegetation:

Following an herbicide application, introducing desirable vegetation has been found to assist in slowing the re-infestation of neyraudia and in preventing soil erosion. Species should be chosen that will compete successfully with neyraudia over the long-term. The Plant Conservation Alliance lists several native grasses that are available and can be substituted for neyraudia:

- Fakahatchee grass (*Tripsacum dactyloides*),
- Switch grass (*Panicum virgatum*),
- Muhly grass (*Muhlenbergia capillaris*).

- In the pine rocklands
  - Bluestem (*Schizachrium rhizomatum*);
  - Wire bluestem (*Schizachyrium gracile*)
  - Wiregrass (*Aristica stricta*)
  - Florida mock gamagrass (*Tripsacum floridanum*).
- In coastal uplands or disturbed sites
  - Pinewoods finger grass (*Eustachys petraea*).

Follow-up:

Regular surveillance of treated and untreated areas will assist in determining if neyraudia is present. In order to maintain the treated area, repeated herbicide treatments may be needed to deal with any new growth that emerges over the next couple of years.

Additional Information

Plant Conservation Alliance: http://www.nps.gov/plants/alien/

The Nature Conservancy's Element Stewardship Abstracts: http://conserveonline.org/

Guinea Grass (*Urochloa maxima*) formerly (*Panicum maximum*)

Guinea grass is native to tropical areas in Africa and is considered an important feed crop for livestock. It is an invasive pest in many tropical areas of the world including Florida, Australia, and Hawaii. In Florida it is common in fields, groves, roadsides and other disturbed sites. It is a drought resistant grass that quickly builds up a high biomass of plant material and when burned, creates hot flashy fires.

Identification

Guinea grass is a tufted perennial that grows 5-10 ft (1.5-3 m) tall. Usually grows in large bunches from short stout rhizomes. Leaf blades are long, narrow, and finely tipped. They are .4 inches (1 cm) wide and have a prominent mid-rib. Seed heads are branched and the oblong seeds are white to purple in color.

Guinea grass. NPS

Fire Effects

Forms dense stands and generates a high fine fuel load that when burned, creates a dangerous blaze. Guinea grass is adapted to fire and will quickly re-colonize an area once burned.

What you need to know:

There is little to no published work on management of guinea grass.

Treatment Options:

Herbicide:

Foliar application of 2% glyphosate.

Biological:

Plants have been noted die rapidly under close continuous grazing.

Follow-up:

Regular surveillance of treated and untreated areas will assist in determining if guinea grass is present. In order to maintain the treated area, repeated herbicide treatments may be needed to deal with any new growth that emerges over the next couple of years

Section VI: Grazing Fuel Treatment

One management option for reducing hazardous fuels is to utilize livestock to decrease ground level fuels. This type of treatment involves fencing off selected areas and allowing livestock such as cows or sheep to forage. This technique is most often applied to wildland urban interface sites, roadsides, and fire breaks.

Best Management Practice

Choosing grazing as a treatment for hazardous fuels
Grazing converts bulk live fuels to organic waste. Targeted grazing can be used to reduce fuel loads of grasses and shrubs. Managers who utilize grazing on areas with hazardous fuel indicated they use cattle to reduce fine fuels such as grass, sheep to reduce saw palmetto, and goats to reduce ladder fuels such as vines.

Selecting a Grazing Method

There are several livestock options available. In Florida, most managers reported using cattle, goats, and sheep for grazing.

Targeted grazing reduces grasses and other herbaceous fuels, but does not reduce dead wood such as branches and logs. Grazing will not reduce all hazardous fuels in a treated area due to the livestock's palette. For instance sheep will consume grasses and palmetto but will not consume gallberry. The fuel reduction achieved by grazing is short-term, plants will resprout following grazing. Grazing is most effective when used in maintaining fuel breaks and applying high impact grazing in areas where prescribed burns are not possible.

Capra hircus adults. UGA

Pros

- Can be low-cost or can create revenue.
- Minimal labor needed if water and fencing are in place.

Cons

- Can compact soils.
- Only affects small diameter vegetation that is < 3".
- Does not reduce dead fuels.
- Fencing and water needed.

Length of effectiveness/re-treatment intervals

- It is necessary to repeat every 1 to 3 years.

Guidelines of Use

Criteria for livestock selection

Each species of grazing animal has different foraging preferences. Cattle prefer grasses, but can consume herbaceous forbs and browse in small amounts. Sheep prefer grasses and forbs, and generally do not eat woody plants. Goats prefer woody plants and shrubs over grasses and forbs. In order to make the most use of targeted grazing, it is important to match the appropriate livestock to the fuel type you are targeting.

Cattle grazing in flatwoods. USDA FS

When selecting a particular livestock it is important to consider the breed. Given Florida's climate, breeds should be chosen that can withstand heat. For instance, hair sheep are a good choice of sheep due to their heat tolerance and parasite resistance. Make sure to discuss the environmental conditions when working with a livestock contractor so that the most appropriate breed of livestock will be selected for the job.

Stocking rates

In order to maximize the amount of fuel consumed by livestock, intensive grazing techniques could be used. This involves using a heavy stocking rate for a short period of time in a multi-week rotational cycle. An example would be to use sheep at a stocking rate of 200 animals per acre for 2-4 days. Stocking rates and rotations would vary by livestock used, and should be discussed with the contracting grazing company. In a study using goats to reduce hazardous fuels, they found that a stocking rate of 600 goats per hectare for one day was significantly effective in reducing fuels. In the same study they also used targeted grazing on a fuel break at a stocking rate of 280 goats per hectare for 3 days, which resulted in significant reduction of cover and biomass.

For more information on grazing for vegetation management see this online handbook:

Targeted Grazing: A Natural Approach to Vegetation Management and Landscape Enhancement
www.cnr.uidaho.edu/rx%2Dgrazing/Handbook.htm

Potential Issues with Grazing Treatments

Ecological Issues

Targeted grazing in general has low impact on treatment sites. While the impact may be low, before selecting this type of fuel treatment method, all potential impacts should be considered.

Invasive Species

Livestock have the potential to transport invasive plant seeds, either in their coat or through their waste. Some managers reported exotic plants could be spread through the supplemental feed that is often supplied for the livestock. This can be minimized by using pellet food instead of feed or by providing no supplemental food at all.

Damage to Non-Target Vegetation
Some non-target tree species may be affected by grazing. Some may be girdled and killed by livestock eating bark. In general there is minimal impact on non-target trees and groundcover.

Wildlife Impacts
Where livestock and wildlife interface, there is a potential for disease transmission. This can happen through contamination of feed and water sources, through parasites such as ticks, and through insects such as mosquitoes.

Public Perceptions of Fuel Treatments
There is strong public approval for using livestock to reduce hazardous fuel. One example of public support is an experiment using grazing to construct fuel breaks in Carson City, Nevada, a program named "Only Ewes Can Prevent Wildfire" a fenced corridor around the city was grazed by ewes (female sheep) resulting in the removal of 71-83% of fine fuels. A survey of nearby homeowners revealed that over 90% supported the project and in addition, they preferred the use of sheep to traditional chemical or mechanical methods of creating fuel breaks.


Goat eating saw palmetto. Karl Schatz

Costs
The cost to rent livestock varies by area and type of animal used. In some cases, you can generate revenue by leasing areas for livestock such as cattle.
The cost for purchasing your own herd is about $200-$500 per head, this does not include maintenance, fencing, and other needs. These costs can later be offset by revenue gained from selling the livestock.

Regulations
Review all Federal, State, Local, and Agency regulations in regards to grazing before beginning this type of treatment to insure compliance.

For more information on regulations see this website:
http://www.sfrc.ufl.edu/Extension/florida_forestry_information/planning_and_assistance/environmental_regulations.html

Or contact your local Florida Division of Forestry office:
www.fl-dof.com
(850) 488-4274

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Appendix A: Prescribed Fire Resources

Florida Division of Forestry

John Saddler
Prescribed Fire Manager
Florida Division of Forestry
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Email: saddlej@doacs.state.fl.us

Prescribed Fire Councils of Florida

North Florida Prescribed Fire Council
Eglin Air Force Base
James Furman, Chairman
AAC/EMSNP 107 Hwy. 85 N
Niceville, FL 32578

Central Florida Prescribed Fire Council
Harry V. Neal, Jr., Past Chair
482 S. Keller Road
Orlando, FL 32810-6101
Telephone: (407) 647-7275 x356

South FL Interagency Fire Management Council
Jon Pasqualone
2401 SE Monterey Road
Stuart, FL 349963
Telephone: (772) 288-5633

U.S. Fish and Wildlife Service

Fire Ecology Field Office at Tall Timbers Research Station
Regional Fire Coordinator Office
13093 Henry Beadel Drive
Tallahassee, FL 32312-0918
Telephone: (850) 893-4153

National Park Service, Everglades

David Loveland, Prescribed Fire Specialist
Fire Management Office
40001 St Rd 9336
Homestead, FL 33034
Telephone: (305) 242-7851

The Nature Conservancy

Florida Fire Manager
Zach Prusak
222 S. Westmonte Drive, Suite 300
Altamonte Springs, FL 32714
Telephone: (407) 682-3664 ex. 138

Pine Rockland Working Group

Chairman: Chris Bergh
The Nature Conservancy
PO Box 420237
Summerland Key, FL 33042
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Southern Center for Wildland-Urban Interface Research and Information

L. Annie Hermansen-Baez
Center Manager / Technology Exchange Coordinator
PO Box 110806. Bldg. 164, Mowry Rd.
Gainesville, FL 32611-0806
Telephone: (352) 376-3271
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Appendix B: Training Resources

Florida Center for Wildfire and Forest Resources Management Training

24059 Childs Road
Brooksville, Florida 34601
Telephone: (352) 754-6780

Florida DOF Prescribed Fire Training

Ms. Johnnie Hurst
Hillsborough Community College
1206 N. Park Road
Plant City, FL 33566-2799
Telephone: (813) 757-2157
Email: jhurst@hccfl.edu

National Interagency Prescribed Fire Training Center

3250 Capital Circle SW
Tallahassee, FL 32310
Telephone: (850) 532-8630

Southern Area Wildland Fire Training

Jan Britt
USDA Forest Service
Telephone: (404) 347-2595
Email: jbritt01@fs.fed.us

Prescribed Fire Councils of Florida

John Saddler
Prescribed Fire Manager
Florida Division of Forestry
Telephone: 850/ 488-9360
Email: saddlej@doacs.state.fl.us

Pesticide Applicator Licenses

Florida Department of Agriculture and Consumer Services
Pesticide Certification Section
3125 Conner Blvd., Bldg. 8 (L-29)
Tallahassee, FL 32399-1650
Telephone: (850) 488-3314
Or contact your local county extension office

Appendix C: Endangered Animals

Common Name	Scientific Name	Designated Status FWC	USFWS	Habitat
AMPHIBIANS				
flatwoods salamander	*Ambystoma cingulatum*	SSC	T	F
gopher frog	*Rana capito*	SSC		F
REPTILES				
key ring neck snake	*Diadophis punctatus acricus*	T		R
Eastern indigo snake	*Drymarchon corais couperi*	T	T	F,R
red rat snake	*Elaphe guttata*	SSC		F,R
Florida brown snake	*Storeria dekayi victa*	T		F,R
rim rock crowned snake	*Tantilla oolitica*	T		R
Florida ribbon snake	*Thamnophis sauritus sackenii*	T		F,R
Florida Key mole skink	*Eumeces egregius egregius*	SSC		R
gopher tortoise	*Gopherus polyphemus*	SSC		F
BIRDS				
Florida sandhill crane	*Grus canadensis pratensis*	T		F
bald eagle	*Haliaeetus leucocephalus*	T	T	F,R
white-crowned pigeon	*Columba leucocephala*	T		R
Kirtland's warbler	*Dendroica kirtlandii*	E		R
red-cockaded woodpecker	*Picoides borealis*	SSC	E	F,R
MAMMALS				
Florida panther	*Puma concolor coryi*	E	E	F,R
Florida black bear	*Ursus americanus floridanus*	T		F
Key deer	*Odocoileus virginianus clavium*	E	E	R
Big Cypress fox squirrel	*Sciurus niger avicennia*	T		F,R
INSECTS				
Miami blue butterfly	*Cyclargus thomasi bethunebakeri*	E		F,R

E=Endangered **T**=Threatened **SSC**=Species of Special Concern **F**=Flatwoods **R**=Rocklands

Listed animal species found in pine rocklands and pine flatwoods communities from Florida Fish and Wildlife Conservation Commission (2004). *Florida's Endangered Species, Threatened Species and Species of Special Concern.* http://myfwc.com/imperiledspecies/pdf/Endangered-Threatened-Special-Concern-2004.pdf.

Appendix D: Flatwoods Listed Plant Species

Species	Scrubby Flatwoods	Mesic Pine Flatwoods	Hydric Pine Flatwoods
Andropogon arctatus (ST)		X	X
Aristida rhizomophora		X	X
Asclepias curtissii (SE)	X		
Asplenium serratum (SE)			X
Bletia purpurea (ST)		X	
Burmannia flava (SE)		X	X
Calopogon multi-florus		X	X
Campyloneurum angustifolium (SE)			X
Campyloneurum costatum (SE)			X
Centrosema arenicola (SE)	X		
Cereus eriophorus var. fragrans (FE,SE)	X		
Chrysophyllum oliviforme (ST)			X
Clitoria fragrans (FT,ST)	X		
Coelorachis tuberculosa (,ST)*			X
Conradina grandiflora (,SE)*	X		
Ctenitis sloanei (SE)			X
Ctenitis submarginis (SE)			X
Cuphea aspera (*)		X	
Deeringothamnus pulchellus (FE,SE)		X	X
Drosera intermedia (ST)			X
Elytraria caroliniensis var. angustifolia (*)			X
Epidendrum rigidum (SE)			X
Eriochloa michauxii var. simpsonii (*)			X
Forestiera segregata var. pinetorum (*)			X
Glandularia maritima (SE)		X	
Glandularia tampensis (SE)		X	
Gymnopogon chapmanianus		X	
Harrisella filiformis (ST)			X
Hartwrightia floridana (,ST)*		X	X
Hypericum edisonianum (SE)			X
Ipomoea tenuissima (SE)			X
Jacquemontia curtissii (,ST)*		X	X
Justicia crassifolia (SE)		X	
Lechea cernua (*)	X		
Lechea divaricata (,SE)*	X		
Liatris ohlingerae (FE,SE)	X		
Licaria triandra (SE)			X
Lilium catesbaei (ST)		X	X
Linum carteri var. smallii (,SE)*		X	
Lythrum flagellare (,SE)*			X
Microgramma heterophylla (SE)			X
Nemastylis floridana (,SE)*		X	X
Nephrolepis biserrata (ST)			X
Nolina atopocarpa (ST)		X	
Nolina brittoniana (FE,SE)	X		

Ophioglossum palmatum (SE)			X
Panicum abscissum (,SE)*			X
Peperomia glabella (SE)			X
Persea humilis	X		
Phyllanthus pentaphyllus ssp. (*)			X
Pinguicula caerulea (ST)		X	X
Pinguicula lutea (ST)		X	X
Platanthera integra (,SE)*		X	
Platanthera nivea (ST)			X
Poinsettia pinetorum (SE)	X		X
Polygala smallii (FE,SE)	X		
Ponthieva brittoniae (SE)		X	
Pteroglossaspis ecristata (ST)		X	
Rhynchospora culixa		X	
Rhynchospora decurren			X
Ruellia noctiora (SE)			X
Scutellaria havanensis (SE)			X
Sphenomeris clavata (SE)			X
Spiranthes brevilabris (SE)			X
Spiranthes laciniata (ST)			X
Spiranthes longilabris (ST)		X	X
Stenorrhynchos lanceolatus (ST)		X	
Stillingia sylvatica ssp. tenuis (*)		X	X
Tephrosia angustissima var. Angustissima (SE)		X	
Tetrazygia bicolor (ST)			X
Thelypteris sclerophylla (SE)			X
Thelypteris serrata (SE)			X
Tillandsia balbisiana (ST)			X
Tillandsia fasciculata (SE)			X
Tillandsia flexuosa (SE)			X
Tillandsia utriculata (SE)			X
Tillandsia valenzuelana (ST)			X
Verbena maritima (SE)		X	
Vernonia blodgettii (SE)		X	X
Warea carteri (FE,SE)	X	X	
Zephyranthes simpsonii (ST)			X

F=Federal **E**=Endangered ***=FWS Species of Management Concern **S**=State **T**=Threatened
No designation= Florida Committee on Rare and Endangered Plants and Animals (non-government) or Florida Natural Areas Inventory (non-government)

Flatwoods Communities Plant Species of Concern from U.S. Fish and Wildlife Service (1999). *South Florida multi-species recovery plan: Appendix C.* Atlanta, Georgia: U.S. Fish and Wildlife Service.

Appendix E: Rocklands Listed Plant Species

Species	Miami Rock Ridge	Big Cypress National Preserve	Florida Keys
Aletris bracteata	X	X	X
Alvaradoa amorphoides	X		
Amorpha herbacea var. crenulata	X		
Argythamnia blodgettii	X		X
Basiphyllaea corallicola	X		X
Bletia purpurea	X	X	X
Bourreria cassinifolia	X		X
Brickellia mosieri	X		
Byrsonima lucida	X		X
Catopsis berteroniana	X		
Chamaesyce deltoidea ssp. adhaerens	X		
Chamaesyce deltoidea ssp. deltoidea	X		
Chamaesyce deltoidea ssp. pinetorum	X		
Chamaesyce deltoidea ssp. serphyllum			X
Chamaesyce garberi	X		X
Chamaecrista lineata var. keyensis			X
Chamaesyce pergamena	X	X	X
Chamaesyce porteriana	X		X
Chaptalia albicans	X		
Coccothrina argentata	X		X
Colubrina arborescens	X		
Colubrina cubensis var. floridana	X		
Crossopetalum ilicifolium	X		X
Crossopetalum rhacoma	X		X
Cynanchum blodgettii	X		X
Cyperus floridanus	X		
Dalea carthagenensis var. floridana	X		
Digitaria dolichophylla	X		X
Digitaria pauciflora	X		
Dodonaea elaeagnoides			X
Ernodea cokeri	X		
Evolvulus grisebachii			X
Galactia smallii	X		
Glandularia maritima	X		
Hypelate trifoliata			X
Ipomoea microdactyla	X		
Ipomoea tenuissima	X		
Jacquemontia curtissii	X	X	X
Jacquinia keyensis	X		X
Jacquemontia pentanthos			X
Koanophyllon villosum	X		
Lantana canescens	X		
Lantana depressa	X		
Linum arenicola	X		X
Linum carteri var. carteri	X		
Linum carteri var. smallii	X	X	

Manilkara jaimiqui ssp. emarginata			X
Melanthera parvifolia	X	X	X
Ocimum campechianum	X		
Odontosoria clavata	X		X
Phyla stoechadifolia	X		
Pisonia rotundata	X		X
Pithecellobium keyense	X		X
Poinsettia pinetorum	X		X
Polygala smallii	X		
Ponthieva brittonae	X		
Psidium longipes	X		X
Psychotria ligustrifolia	X		
Pteris bahamensis	X	X	X
Pteroglossaspis ecristata	X		
Rhynchosia parvifolia	X		X
Sachsia polycephala	X		X
Scutellaria havenensis	X		X
Selaginella eatonii	X		
Senna meicana var. chapmanii	X		X
Smila havanensis	X		X
Solanum verbascifolium	X		
Spermacoce terminalis	X		X
Spiranthes torta	X		X
Strumpfia maritima			X
Stylosanthes calcicola	X		X
Tephrosia angustissima	X		
Tephrosia angustissima var. corallicola	X		
Thrina morrisii			X
Thrina radiata			X
Tillandsia balbisiana	X	X	X
Tillandsia fasciculata var. densispica	X	X	X
Tillandsia fleuosa	X	X	X
Tillandsia utriculata	X	X	X
Tillandsia variabilis	X	X	X
Tragia saicola	X		
Trema lamarckianum	X		
Tripsacum floridanum	X	X	X
Vernonia blodgettii	X	X	X
Warea carteri	X		

Distribution of listed plant species in pine rocklands from U.S. Fish and Wildlife Service (1999). *South Florida multi-species recovery plan: Pine Rocklands*. Atlanta, Georgia: U.S. Fish and Wildlife Service.

Appendix F: Endemic Plant Species of Pine Rocklands

Species
Amorpha herbacea var. crenulata
Argythamnia blodgettii
Brickellia mosieri
Chamaecrista lineata var. keyensis
Chamaesyce conferta
Chamaesyce deltoidea ssp. adhaerens
Chamaesyce deltoidea ssp. deltoidea
Chamaesyce deltoidea ssp. pinetorum
Chamaesyce deltoidea ssp. serphyllum
Chamaesyce garberi
Chamaesyce porteriana
Dalea carthagenensis var. floridana
Digitaria pauciflora
Elytraria caroliniensis var. angustifolia
Galactia pinetorum
Galactia smallii
Hedyotis nigricans var. floridana
Jacquemontia curtisii
Lantana depressa var. depressa
Linum arenicola
Linum carteri var. carteri
Linum carteri var. smallii
Melanthera parvifolia
Phyllanthus pentaphyllus var. floridanus
Poinsettia pinetorum
Ruellia succulenta
Sabal miamiensis
Sideroxylon reclinatum ssp. austrofloridense
Spermacoce terminalis
Tephrosia angustissima
Tragia saxicola

Endemics occurring in pine rocklands from U.S. Fish and Wildlife Service (1999). *South Florida multi-species recovery plan: Pine Rocklands.* Atlanta, Georgia: U.S. Fish and Wildlife Service.

Appendix G: Managers Interviewed

Pine Rocklands Workshop

Name	Title	Agency
Rick Anderson	Fire Ecologist	Everglades National Park Fire Management
Chris Bergh	Conservation Program Manager, Florida Keys	The Nature Conservancy
Gwen Burzyck	Environmental Resources Project Supervisor	Miami-Dade DERM
Chuck Byrd	Land Steward Coordinator	The Nature Conservancy, Florida Keys
Hillary Coolley	Biological Technician	Everglades National Park
Jim Durrwachter	Fire Mgt. Officer- Forester	Florida Panther NWR
Don Gann		Private Property Owner
Joyce Gann		Private Property Owner
Barbara Glancy	Owner/Manager	Pine Ridge Sanctuary
Terry Glancy	Owner/Manager	Pine Ridge Sanctuary
Robin Gray-Urgelles	Biologist I	Miami-Dade DERM, Endangered Lands Program
Steven Green	Biologist	The Institute for Regional Conservation
Alison Higgins	Land Conservation Program Manager	The Nature Conservancy, Florida Keys
Tim Joyner	Inspector II Forest Resources Program	Miami-Dade DERM
Suzanne Koptur	Professor	FIU Biology Department
Pam Krauss	President	Permitting Assessment and Management, INC.
Marcos Loperena	Soil Conservationist	USDA-NRCS
Anne Morkill	Refuge Manager	US Fish and Wildlife Service-Florida Keys National Wildlife Refuge
Erin Myers	State Biologist	USDA Natural Resources Conservation Service
Josh O'Connor	Prescribed Fire Specialist	US Fish and Wildlife Service
Erick Revuelta	Biologist II	Miami-Dade DERM
Julissa Roncal	Project Plant Ecologist	Fairchild Tropical Botanic Garden
Mike Ross	Associate Professor	Florida International University
Jay P. Sah	Assistant Research Scientist	Southeast Environmental Research Center/FIU
James Snyder	Research Biologist	USGS, Florida Integrated Science Center
PJ Stevko		FWS
Sonja Thompson	Restoration Biologist	Miami-Dade County- Natural Area Management
Alberto Vega		URS Corp
Kristie Wendelberger	Field Botanist/Permit Coordinator	Fairchild Tropical Botanic Garden
Dallas Hazelton	Environmental Resources Project Supervisor	Miami-Dade County Parks/ Natural Areas Management

Pine Flatwoods Workshop

Name	Title	Agency
Fred Adrain	Administrative Forester	U.S. Fish and Wildlife Service, Merritt Island NWR
John Aspiolea	Assistant Park Manager	Florida Park service/Charlotte Harbor Preserves State Park
Kris Brown	Land Management Tech.	Brevard County Endangered Lands Program
Brian Christ	Wildlife Technician	FL Fish and Wildlife Conservation Commission
Roger Clark	Land Steward Manager	Lee County Parks & Recreation
Patricia Cross	Assistant Park Manager	DEP, FL Park Service, Hillsborough River State Park
Diana Donaghy	Biological Scientist II (park biologist)	DEP, Division of parks and Recreation, Myakka River State Park
Keith Fisher	Director: Disney Wilderness Preserve	The Nature Conservancy
William Frankenberger	Natural Resources Liaison	FL Department of Military Affairs
Jim Green	Land Steward Coordinator	Lee County Parks & Recreation
Laura Greeno	Land Steward Coordinator	Lee County Parks & Recreation
Kraig Krum	Fire Management Coordinator	Palm Beach County/DERM
Sara Leitman	Environmental Specialist	Alachua County Environmental Protection Department
Christopher Matson	TNC Restoration Projects Coordinator, Disney Wilderness Preserve	The Nature Conservancy
Steve McGuffey	Assistant Land Manager	Brevard County Environmentally Endangered Lands Program
Kelly McPherson	Environmental Specialist	Alachua County Environmental Protection Department
Vince Michault	South Region Assistant Land Manger	Brevard County Environmentally Endangered Lands Program
Clarence Morgan	Rangeland Management Specialist	US Air Force Avon Park AFR
Steve Morrison	Conservation Program Manager-Lake Wales Ridge	The Nature Conservancy
Robert Nelson	Conservation projects Manager, Disney Wilderness Preserve	The Nature Conservancy
Chris O'Hara	South Region Land Manger	Brevard County Environmentally Endangered Lands Program
Cathy Olson	Senior Supervisor Land Stewardship	Lee County Conservation 20/20
Kris Price	Environmental Lands Foreman	Polk County BoCC Natural resource division
Zachary A. Prusak	Florida Fire Manager	The Nature Conservancy
Marcia Rickey	Research Assistant	Archbold Biological Station
Gaye Sharpe	Natural Areas Manger	Polk County BoCC Natural Resource Division
James Snyder		USGS, Florida Integrated Science Center
Wayne Taylor	Natural Resource Specialist	USAF/APAFR
Karen Vallar	Hydrology Program Manager	US Air Force Avon Park AFR
Sam Van Hook	Kissimmee Valley Forester	USAF
Dean Vanderbleek	Fire Manager	Brevard County Environmentally Endangered Lands Program
Tod Zechiel	NEPA Coordinator	USAF

The following tables display a comparison of hazardous fuels treatment options adapted from *Wildfire Mitigation in Florida* published by the Florida Department of Community Affairs, (2004) Jacksonville, FL: Drummond Press.

Fuel Treatment	Advantages	Concerns	Potential Impacts	Seasonality and intensity of treatment	Application in WUI	Duration of effect	Cost
Mowing	• Reduces shrubs to ground • Turns some fuels into mulch • Encourages herbaceous growth and generally increases species diversity • Requires limited equipment and personnel • Relatively independent of weather • Causes little disturbance to ground cover	• Does not reduce amount of fuel, merely changes structure • Has little impact to roots, so species like palmetto resprout quickly • Unsightly • Difficult to apply with overstory present	• Low risk to public safety, except material can be thrown up to 300 feet from large mowers • May cause some temporary degradation of local air quality from dust	• Can be done in almost any season, but must be done at moderate moisture levels to limit soil disturbance • Intensity is dependant on the size and design of the mower. Larger mowers mulch material better but encounter more obstacles • Can treat up to 10 acres/day	Difficulty depends on the number of obstacles to machinery	3-5 years	$40-$900 per acre
Chipping, Disking, Harrowing	• Reduces shrubs to ground • Disrupts resprouting of some shrubs (palmetto) • Encourages herbaceous growth • Generally increases species diversity • Requires limited equipment and personnel • Relatively independent of weather • Harrow exposes bare soil, limiting fire potential until regrowth occurs	• Does not reduce amount of fuel, merely changes structure • Difficult to apply with overstory present • Can disrupt root systems of some desirable vegetation (e.g. trees) • Unsightly • Harrowing exposes bare soil, increasing potential for erosion and invasive plant colonization	• Low risk to public safety • Significant risk to overstory trees due to root damage • May cause some temporary degradation of local air quality from dust	• Can be done in almost any season, but must be done at moderate moisture levels to limit soil disturbance • Intensity is dependent on the size and design of the chopper, disk or harrow • Can treat up to 10 acres/day	Difficulty depends on number of obstacles to machinery	3-7 years	$70-$110 per acre

Herbicides	• Can be applied to kill target species or all growth • Easy to apply • Provides long-term impact • Does not physically disturb soil • Limits opportunity for invasive plants • Generally independent of weather	• May encounter public opposition • Does not remove fuel • Creates increased flammability for a period immediately following treat (standing dead fuels)	• May affect non-target species or overstory trees if improperly applied • May have unknown or unforeseen risks to public health, depending on chemical used	• Must be applied during growing season • Intensity is dependant on chemical and application rates • Can treat up to 15 acres/day	Difficulty based on concern of neighbors, level of toxicity	Up to 10 years	$70-$110 per acre

Fuel Treatment	Advantages	Concerns	Potential Impacts	Seasonality and intensity of treatment	Application in WUI	Duration of effect	Cost
Thinning	• Reduces risk of crown fire by separating trees • May generate revenue • Equipment runs over and compacts shrubs • Minimal soil disturbance • Moderately dependent on weather • Encourages herbaceous growth	• Removes some crown fuel, but does not remove ground-level fuel • May encounter public opposition • Requires proper (moderate moisture) conditions • Creates increased flammability for the period immediately following treatment (slash residue) • Requires >20 acres to generate positive revenue	• Equipment may damage retained trees • May cause some temporary degradation of local air quality (dust)	• Need to avoid excessively wet periods to limit soil disturbance • Intensity depends on volume of tress harvested • Can treat up to 15 acres/day	Difficulty based on site features, concern of neighbors	5-7 years	Will produce revenue with enough volume and acreage
Grazing (biomass conversion)	• Defoliates most shrubs from ground up to 5 feet • Converts bulk of live and dead fuel to organic waste • Compacts duff, making it less likely to burn • Encourages herbaceous growth, favoring grasses • Generally increases species diversity • Easy to apply in the presence of obstacles • Minimal impact on non-target species (trees) and groundcover • Requires limited personnel and equipment • Strong public approval	• Costly on small lots due to animal transportation • Fencing or containment systems are necessary • Few operators are available • Need animal shelter or caretaker near site • Some desirable tree species may be girdled and killed by livestock eating bark • Supplemental mitigation methods may be necessary as livestock may not eat certain flammable plants (e.g., sheep eat saw palmetto but not gallberry)	• Very low risk to public safety • Animals may transport invasive plants, diseases, or pest species to site	• Can be implemented most of the year • Intensity depends on objectives: multiple treatments are necessary to kill woody plants; if used with other treatments, periodic grazing can maintain a site indefinitely • Can treat up to 10 acres a day with a large flock	Very useful in most areas, costly in smaller areas	2-5 years, depending on vegetation type and number of passes	$200-$500 per acre; can be used to produce meat or revenue